SOCIETY OF ECOLOGICAL CHEMISTRY AND ENGINEERING

ECOLOGICAL CHEMISTRY AND ENGINEERING A

CHEMIA I INŻYNIERIA EKOLOGICZNA A

Vol. 18 No. 1

OPOLE 2011

EDITORIAL OFFICE
Opole University
ul. kard. B. Kominka 4, 45–032 OPOLE, PL
phone +48 77 455 91 49
email: waclawek@uni.opole.pl
http://tchie.uni.opole.pl

SECRETARIES
Agnieszka Dołhańczuk-Śródka, phone +48 77 401 60 46, email: agna@.uni.opole.pl
Małgorzata Rajfur, phone +48 77 401 60 42, email: mrajfur@o2.pl

SECRETARIES' OFFICE
phone +48 77 401 60 42
email: mrajfur@o2.pl

Ecological Chemistry and Engineering A / Chemia i Inżynieria Ekologiczna A
is partly financed by Ministry of Science and Higher Education, Warszawa

ISSN 1898–6188

CONTENTS

VARIA

SPIS TREŚCI

VARIA

AArticles published in this issue were presented during Scientific Conference "HORTICULTURE OF TOMORROW – CHALLENGES AND RISKS", that took place on 10–11 September 2009 in Krakow. The conference was organized by the Polish Society for Horticultural Science and the Faculty of Horticulture of Agricultural University in Krakow and co-financed by the Ministry of Science and High Education. All articles have been reviewed.

220 participants represented Faculties of Horticulture of three Polish universities: Wroclaw University of Environmental and Life Sciences, Poznan University of Life Sciences and University of Life Sciences in Lublin, and also from Warsaw University of Life Sciences – SGGW, University of Technology and Life Sciences in Bydgoszcz, West Pomeranian University of Technology in Szczecin, University of Warmia and Mazury in Olsztyn, University of Podlasie, University of Rzeszow, Public Technical Higher School in Sandomierz, School of Engineering and Economic in Ropczyce, Agricultural University of Plovdiv (Bulgaria) and Agricultural University in Krakow. Also scientists from some institutes such as Research Institute of Vegetable Crops, Research Institute of Pomology and Floriculture in Skierniewice, Institute of Natural Fibres and Medicinal Plants and Institute of Biopolymers and Chemical Fibres in Lodz took part in the conference.

We would like to thank sincerely our sponsors for their financial support. We would also like to thank all Authors, Reviewers and Editors of this issue.

Artykuły opublikowane w tym zeszycie były prezentowane podczas Ogólnopolskiej Konferencji Naukowej pt. „OGRODNICTWO JUTRA – WYZWANIA I ZAGROŻENIA", 10–11 WRZEŚNIA 2009, KRAKÓW. Konferencja została zorganizowana przez Polskie Towarzystwo Nauk Ogrodniczych i Wydział Ogrodniczy Uniwersytetu Rolniczego w Krakowie. Prezentowane artykuły przeszły normalną procedurę recenzyjną i redakcyjną. Konferencja była dofinansowana przez Ministra Nauki i Szkolnictwa Wyższego.

Uczestnicy w liczbie 220 reprezentowali 3 Wydziały Ogrodnicze Uniwersytetów Przyrodniczych we Wrocławiu, Lublinie i Poznaniu oraz SGGW w Warszawie, Uniwersytet Technologiczno-Przyrodniczy w Bydgoszczy, Zachodniopomorski Uniwersytet Technologiczny w Szczecinie, Uniwersytet Warmińsko-Mazurski w Olsztynie, Akademię Podlaską w Siedlcach, Uniwersytet Rzeszowski, Państwową Wyższą Szkołę Zawodową w Sandomierzu, Wyższą Szkołę Inżynieryjno-Ekonomiczną w Ropczycach, Uniwersytet Rolniczy w Płowdiw (Bułgaria) oraz Uniwersytet Rolniczy w Krakowie. W Konferencji wzięli udział także pracownicy naukowi instytutów branżowych IW i ISK w Skierniewicach, Instytutu Włókien Naturalnych i Roślin Zielarskich w Po-

znaniu, Instytutu Biopolimerów i Włókien Chemicznych w Łodzi, a także przedstawiciele sponsorów, którym pragniemy serdecznie podziękować za wsparcie finansowe.

Wyrażamy również serdeczne podziękowania wszystkim Autorom, Recenzentom oraz Redaktorom odpowiedzialnym za przygotowanie zeszytu.

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Anita BIESIADA[1], Agnieszka NAWIRSKA[2],
Alicja KUCHARSKA[2] and Anna SOKÓŁ-ŁĘTOWSKA[2]

CHEMICAL COMPOSITION OF PUMPKIN FRUIT DEPENDING ON CULTIVAR AND STORAGE

SKŁAD CHEMICZNY OWOCÓW DYNI W ZALEŻNOŚCI OD ODMIANY I PRZECHOWYWANIA

Abstract: The investigation carried out in the years 2006–2008 aimed at the assessment of pumpkin fruit of 12 cultivars belonging to *Cucurbita maxima* (‘Amazonka’, ‘Ambar’, ‘Bambino’, ‘Karowita’, ‘Melonowa Zolta’, ‘Uchiki Kuri’) and *Cucurbita pepo* (‘Danka Polka’, ‘Miranda’, ‘Junona’, ‘Pyza’ and ‘Warszawska Makaronowa’, as well as ‘Jet’ F_1). The evaluation involved the content of carotenoids, vitamin C, starch, polyphenols, soluble solids, dry matter, total and reducing sugars, as well as nitrates and macroelements (P, K, Mg, Ca) in pumpkin fruit immediately after harvest and after 90-day storage in gravity storehouse. Pumpkin was cultivated from transplants planted to a destination site in the second decade of May.

Mature pumpkin fruits were harvested in the second week of September. Cultivars of *Cucurbita maxima* featured higher content of carotenoids, vitamin C, starch, soluble solids, dry matter, total and reducing sugars than those belonging to *Cucurbita pepo*. The highest content of carotenoids was recorded in ‘Amazonka’ (18.40 mg $\cdot$ 100 g^{-1} f.m.) and ‘Ambar’ (15.49 mg $\cdot$ 100 g^{-1} f.m.) cvs. The richest source of starch proved to be fruits of ‘Ambar’ (61.5 mg $\cdot$ 100 g^{-1} f.m.), ‘Amazonka’(31.3 mg $\cdot$ 100 g^{-1} f.m.) and ‘Uchiki Kuri’ (20.95 mg $\cdot$ 100 g^{-1} f.m.) cvs. Different levels of total phenolics in pumpkin fruit of all estimated cultivars were less visible as far as carotenoids, vitamin C and starch contents were concerned. After 90 days of storage contents of carotenoids, vitamin C, starch, total and reducing sugars, dry matter and nitrates as well as pH value decreased, while the level of potassium, phosphorus, magnesium and calcium increased. There was not observed significant decrease in total phenolics content in fruits of *C. maxima* and *C. pepo* after storage.

Keywords: pumpkin species, cultivars, storage, chemical composition of pumpkin fruit

Pumpkin fruit is a rich source of valuable nutrient components, such as carotenoids, potassium, vitamins C, B_2, and E, characterizes low energetic content and high amount of fiber [1, 2], which allows to produce different foods for adults and infants (as a component of purees, jellies, jams, juices).

[1] Department of Horticulture, Wroclaw University of Environmental and Life Sciences, pl. Grunwaldzki 24a, 50–363 Wrocław, Poland, phone: +48 71 320 1716, email: anita.biesiada@up.wroc.pl

[2] Department of Fruit Vegetables and Cereals Technology, Wroclaw University of Environmental and Life Sciences, ul. C.K. Norwida 25, 50–375 Wrocław, Poland, phone: +48 71 320 77 12, email: agnieszka.nawirska@up.wroc.pl

Carotenoids derived from pumpkin fruit can be used as natural food colorant [3]. Pumpkin fruit is a crop with good preservation capacity but regarding good quality of product pumpkins generally cannot be stored beyond 90 days, even in ideal storage conditions [4, 5]. In Poland there are grown two species of pumpkin *Cucurbita maxima* and *Cucurbita pepo*. Among botanical varieties of *C. pepo* the most popular are zucchini and pattypan squash type cultivated for immature fruit crop, whereas the production of cultivars for fully mature fruit crop is less popular in Poland.

The purpose of the research conducted in the years 2006–2008 was the assessment of fruit quality of 12 pumpkin cultivars classified to two species – *C. maxima* and *C. pepo* directly after their harvesting and after storage.

Materials and methods

Three-year field experiment was carried out in the Experimental Station of Wroclaw University of Environmental and Life Sciences on fine clay soil containing 1.8 % of organic matter, of pH = 7.15 and high content of phosphorus (90–125 mg $\cdot$ dm^{-3}) potassium (220–240 mg $\cdot$ dm^{-3}) and magnesium (80–100 mg $\cdot$ dm^{-3}).

The experiment was established as two-factors pattern, in four replications. The plot area was 6.0 m^2 (3.0 × 2.0 m). There were estimated different cultivars of *Cucurbita maxima* (‘Amazonka’, ‘Ambar’, ‘Bambino’, ‘Karowita’, ‘Melonowa Zolta’ and ‘Uchiki Kuri’) and *Cucurbita pepo* (‘Danka Polka’, ‘Jet’ F_1, ‘Junona’ ‘Miranda’, ‘Pyza’ and ‘Makaronowa Warszawska’) cultivated from transplants. Ammonium nitrate was used in dose of 200 kg N $\cdot$ ha^{-1} as a broadcast (100 kg N $\cdot$ ha^{-1}) and top dressing (100 kg N $\cdot$ ha^{-1}) application. Seed were sown in the second week of April to multicells filled with peat substrate (126 cm^3 per one cell). Transplants were planted to the field in spacing 1.5 × 1 m in the second week of May.

Crop management was conducted according to commonly accepted standards for these species. Harvest took place in the second week of September.

At harvest 3 fruits per plot were sampled for chemical analysis, the rest of the crop was kept in storage house with gravity ventilation at the temperature of 10 ^{o}C and RH 75 %. After 90 days of storage fruit samples were collected in the same amounts. They were prepared by cutting pumpkin fruit, removing the placenta and seeds, milling the flesh with blender. Immediately after harvesting and at the end of storage there were assayed the contents of vitamin C (Tillman’s method), total carotenoids [6], total and reducing sugars (by Lane-Eynon method), soluble solids in degree of Brix scale using refractometer (ATAGO-POCTEL), as well as dry matter by drying to constant weight at 105 ^{o}C. Nitrates were determined using an ion-selective electrode. The content of total phenolic compounds was determined according to Folin-Ciocalteu method [7]. The contents of macroelements: phosphorus, potassium, magnesium and calcium were assayed due to Nowosielski method [8].

The data collected from 3 years were subjected to analysis of variance and mean values were separated by the Tuckey’s test at $p = 0.05$.

Results and discussion

Fruits of *C. maxima* contained over three to five times higher level of total carotenoids and vitamin C than cultivars of *C. pepo* (Table 1). Among tested cultivars belonging to *C. maxima* species the highest content of carotenoids was detected in 'Amazonka' (18.40 mg · 100 g^{-1} f.m.) and 'Ambar' (15.49 mg · 100 g^{-1} f.m.), while the lowest one in 'Melonowa Zolta' (4.14 mg · 100 g^{-1} f.m.). The highest carotenoids content in 'Amazonka' was also reported by Sztangret et al [9], Gajc-Wolska et al [10], Pauluskiene et al [11] and Kahkonen et al [12]. Fruit of 'Amazonka' and 'Ambar' were the richest source of vitamin C (34.97 and 42.48 mg · 100 g^{-1} f.m., respectively) among tested cultivars. Low quantity of this vitamin was observed in fruit of 'Miranda' and 'Junona' cvs. The richest source of starch were fruits of 'Ambar', 'Amazonka' and 'Uchiki Kuri' cvs and the lowest – fruits of 'Pyza' and 'Warszawska Makaronowa' cvs. Differences in the level of total phenolic compounds in pumpkin fruit regarding all estimated cultivars were less visible than in the case of carotenoids, vitamin C and starch contents. The amount of total phenolics varied widely in edible plant material and in cereals it proved to be the lowest one (0.2–1.3 mg · g^{-1} GAE d.m.), berries contained relatively high amounts of phenolics (12.4–50.8 mg · g^{-1} GAE d.m.) and in vegetables its level ranged from 0.4 to 6.6 mg · g^{-1} GAE d.m. [12]. According to Vinson et al [13], in the group of 22 analyzed vegetables beans, beet, corn and broccoli showed the highest total phenolics content per fresh mass. Similar content of phenolics, comparable with that of pumpkin, was assayed in carrot [14] but higher content of polyphenols was found in such vegetables as red beet or onion [15].

Table 2 shows the content of total and reducing sugars, as well as soluble solids, dry matter and pH of fruit of 12 pumpkin cultivars before and after storage. Higher level of reducing and total sugars was found in fruits of 'Amazonka' cv. (5.04 and 6.00 % f.m., respectively) and 'Uchiki Kuri' cv. (5.16 and 5.52 % f.m., respectively) and the lowest – in fruits of cultivars 'Pyza' (1.87 and 2.56 % f.m., respectively) and 'Miranda' (1.61 and 2.04 % f.m., respectively). In the remaining cultivars the contents of sugars ranged from 3.13 to 2.40 % f.m. for reducing sugars and from 4.45 to 3.15 % f.m. for total sugars.

The pH value of *C. maxima* fruit varied from 7.42 to 6.67 and was higher than in *C. pepo* pumpkin (6.01–6.75). This parameter is used to determine acidity of the flesh and it decides about microbiological durability of products destined for processing. Among vegetables, pumpkin and red beet (pH = 7.1) feature very high pH [15]. The results obtained in this study are similar to those reported by Pauluskiene et al [11] but according to Pijanowski et al [15] pH of pumpkin fruit varied from 4.6 to 5.1.

Dry matter and soluble solids contents of *C. maxima* fruit were relatively higher than those observed in *C. pepo*. Among tested cultivars of *C. maxima* the lowest levels of soluble solids and dry matter were determined in 'Melonowa Zolta' and 'Bambino' fruit and among the cultivars of *C. pepo* the highest content of this components were found in edible parts of 'Danka Polka' and 'Jet' F_1. Also in the study by Pauluskiene et al [11] there was observed high content of dry matter in fruits of 'Amazonka' and 'Ambar' cvs.

Table 1

The effect of cultivar on content of carotenoids, vitamin C, phenolics and starch in pumpkin fruit before and after storage (mean values for 2006–2008)

Cultivar	Carotenoids		Vitamin C		Phenolics		Starch	
	$[mg \cdot 100\ g^{-1}$ f.m.]							
	1*	2	1	2	1	2	1	2
Amazonka	18.40	11.69	34.97	19.33	29.82	22.38	31.26	4.80
Ambar	15.49	7.42	42.48	30.82	18.05	20.36	61.45	15.47
Bambino	10.39	5.24	26.05	14.42	22.27	23.57	6.14	7.39
Karowita	10.41	11.12	29.18	18.61	22.71	25.27	7.53	5.51
Melonowa Zolta	4.14	2.98	19.93	16.23	14.75	22.81	7.31	7.01
Uchiki Kuri	9.48	6.24	21.02	16.10	19.79	23.17	20.95	13.44
Danka Polka	2.67	2.71	21.11	8.61	22.62	18.78	4.50	4.77
Junona	2.17	0.98	9.22	4.15	23.10	17.46	6.70	5.22
Miranda	0.98	1.14	5.54	4.76	19.33	18.37	4.44	5.17
Pyza	0.16	0.66	13.30	5.64	18.18	14.50	1.01	4.17
Warszawska Makaron.	2.11	0.31	14.37	7.74	22.37	22.25	2.56	5.17
Jet F1	0.57	0.26	10.80	3.86	24.90	23.27	8.06	4.93
Mean	6.41	4.22	20.66	12.52	21.49	21.01	13.49	6.92
LSD $\alpha = 0.05$ for:								
cultivar	0.34	0.46	0.61	0.84	0.72	1.24	0.75	0.82
storage		0.36		1.16		n.s.		1.11

* 1 – before storage, 2 – after storage; n.s. – not significant.

Table 2

The effect of cultivar on content of total and reducing sugars, dry matter and soluble solids as well as pH value in pumpkin fruit before and after storage (mean values for 2006–2008)

Cultivar	Soluble solids [° Brix]		Dry matter [%]		pH		Reducing sugars [% f.m.]		Total sugars [% f.m.]	
	1*	2	1	2	1	2	1	2	1	2
Amazonka	9.70	6.96	13.73	9.14	7.42	6.92	5.04	3.81	6.00	5.75
Ambar	9.96	11.93	19.02	15.44	7.38	7.51	2.47	3.20	3.98	3.72
Bambino	6.26	5.80	8.06	6.47	6.76	6.89	2.72	3.08	4.21	4.40
Karowita	6.90	7.23	9.21	8.00	7.12	6.82	3.13	2.72	4.28	2.87
Melonowa Zolta	5.13	4.93	7.16	7.15	6.67	6.30	2.65	2.21	3.35	2.65
Uchiki Kuri	9.53	9.10	11.99	11.50	6.84	7.24	5.16	3.22	5.52	4.37
Danka Polka	6.76	6.06	8.13	7.38	6.65	5.84	2.73	2.16	3.87	2.47
Junona	5.53	3.90	7.32	5.17	6.31	6.15	2.40	1.26	3.02	1.60
Miranda	3.70	3.70	4.82	4.88	6.37	6.40	1.61	0.94	2.04	1.72
Pyza	4.53	3.86	5.28	4.91	6.64	6.15	1.87	1.64	2.56	2.02
Warszawska Makaron.	4.51	5.40	5.28	6.84	6.01	6.33	2.74	1.49	3.15	2.30
Jet F_1	7.40	7.10	9.46	8.81	6.75	6.04	2.87	3.05	4.45	3.83
Mean	6.65	6.33	9.12	7.97	6.74	6.54	2.94	2.39	3.89	3.14
LSD $\alpha = 0.05$ for:										
cultivar	1.23	1.36	0.96	1.05	0.23	0.36	0.48	0.46	0.58	0.46
storage		n.s.		1.11		n.s.		0.37		0.42

* 1 – before storage, 2 – after storage; n.s. – not significant.

After 90 days of storage contents of carotenoids, vitamin C, starch, total and reducing sugars, soluble solids and dry matter as well as pH value decreased. On average, after storage the level of vitamin C decreased in pumpkin fruit by 40 %. The loses of this compound were over 50 % in fruits of ‘Uchiki Kuri’, ‘Danka Polka’, ‘Warszawska Makaronowa’ and ‘Jet’ F_1 cvs.

Content of carotenoids in pumpkin fruit decreased on average by 35 % after storage. Especially high loses of this component were observed in fruit of ‘Ambar’, ‘Bambino’, ‘Jet’ F_1, and ‘Warszawska Makaronowa’ cvs. There was recorded slight increment in content of carotenoids, in fruit of ‘Karowita’, ‘Danka Polka’ and ‘Miranda’ and ‘Pyza’. The fruits featuring more intensive process of caroten synthesis in the post–harvest period were mainly representatives of cultivars with low level of this compound after harvest. Probably their fruit did not reach full maturity when harvested and their ripening took place in the course of their storage. According to Iacuzzo and Dalla Costa [16] content of carotenoids did not significantly change during storage: within two years of a three–year study the level of these pigments increased but in the third year its decreased amount became a fact. Noseworthy and Loy [17] did not observe significant changes in carotenoids content in pumpkin fruit between 30 and 60 days of storage. Arvayo-Ortiz et al [18] and Bycroft et al [19] found that carotenoids level increases according to storage time as a result of post-harvest fruit metabolism. The other authors [20] reported β-carotene content decline between 8 and 12 weeks of storage.

The contents of starch decreased especially in fruit of “high starch cultivars” (‘Ambar’ 75 %, ‘Amazonka’ 84 %, ‘Uchiki Kuri’ 35 % and ‘Jet’ F_1 39 %). In fruit of ‘Pyza’ and ‘Warszawska Makaronowa’ starch content increased after storage from 1.01 and 2.56 to 4.17 and 5.17 mg $\cdot$ 100 g^{-1} f.m., respectively. Iacuzzo and Dalla Costa [16] reported the decrease in starch amount by two thirds after 12 weeks of storage, while sugars were decomposed and degraded to mono- and disaccharides.

In the experiment there was observed significant decrease of dry matter content but differences in soluble solids level in pumpkin fruit before and after storage were rather negligible. Similar results were obtained by Philips [21]. Niewczas and Mitek [22] did not noted any significant changes in the level of these components.

There was not found any significant decrease in total phenolics content in fruits of *C. maxima* and *C. pepo* during storage. Also Burda et al [23] did not notice any changes in phenolics content in apples and blueberries during their maturation in cold storage chamber.

The content of nitrates in pumpkin fruit depended on species and cultivar (Table 3). Higher concentration of nitrates was observed in fruit of *C. pepo* (800–2100 mg $\cdot$ 100 g^{-1} f.m.) with only one exception of ‘Jet’ F_1 which fruit had the lowest level of this compound (290 mg $\cdot$ 100 g^{-1} f.m.). The level of nitrates in pumpkins of *C. maxima* varied from 390 to 690 mg $\cdot$ 100 g^{-1} f.m.) depending on cultivar. *C. pepo* fruit characterized higher content of potassium, magnesium, phosphorus and calcium than those belonging to *C. maxima* species. After storage the content of nitrates decreased, while the level of potassium, phosphorus, magnesium and calcium increased.

Storability of tested cultivars did considerably vary within the year of study. In rainy 2007 [data not presented] there was observed the highest percentage of rotten fruits

Table 3

The effect of cultivar on chemical composition of pumpkin fruit before and after storage (mean values for 2006–2008)

Cultivar	NO_3-N [mg · 100 g^{-1} f.m.]		P		K		Mg		Ca	
			[% d.m.]							
	1*	2	1	2	1	2	1	2	1	2
Amazonka	650	230	0.32	0.40	4.59	6.45	0.14	0.14	0.23	0.41
Ambar	390	170	0.17	0.22	2.75	3.83	0.12	0.14	0.16	0.33
Bambino	690	400	0.38	0.40	4.55	6.67	0.14	0.19	0.29	0.45
Karowita	450	250	0.31	0.30	4.75	5.51	0.12	0.15	0.18	0.33
Melonowa Zolta	570	350	0.36	0.46	4.89	5.70	0.14	0.16	0.32	0.40
Uchiki Kuri	630	210	0.26	0.28	4.00	4.12	0.12	0.15	0.19	0.33
Danka Polka	800	320	0.36	0.40	5.65	7.57	0.16	0.20	0.27	0.42
Junona	855	230	0.51	0.49	5.00	8.85	0.23	0.30	0.29	0.55
Miranda	960	390	0.48	0.60	6.37	9.02	0.25	0.28	0.49	0.64
Pyza	1220	1020	0.44	0.49	5.56	7.72	0.17	0.22	0.46	0.82
Warszawska Makaron.	2100	2080	0.34	0.32	6.62	8.41	0.16	0.20	0.32	0.49
Jet F1	290	280	0.54	0.38	4.77	6.20	0.17	0.14	0.36	0.45
Mean	875	570	0.34	0.39	4.95	6.67	0.16	0.19	0.29	0.46
LSD α = 0.05 for:										
cultivar	65	74	0.04	0.03	0.31	0.42	0.02	0.03	0.03	0.02
storage		87		0.04		0.54		0.02		0.04

* 1 – before storage, 2 – after storage.

during 90 days of storage, especially in 'Bambino' (38 %), 'Karowita' (36 %) and 'Melonowa Zolta' (38 %) cultivars (Fig. 1).

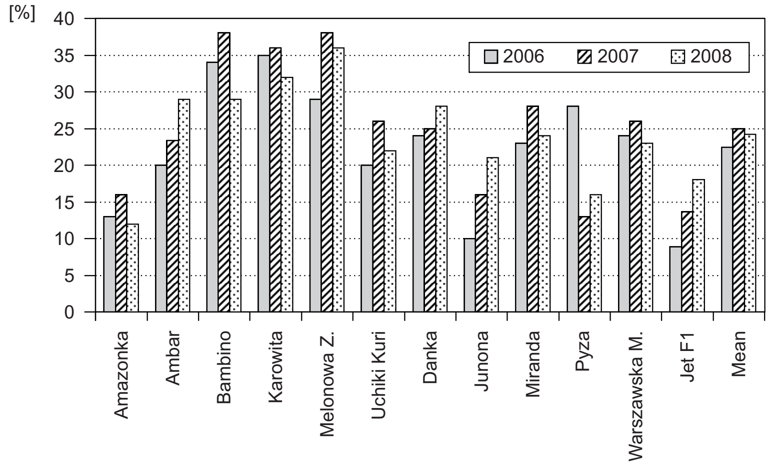

Fig. 1. Percentage of rotten fruits during 90-day storage period in relation to cultivars and particular year of the experiment

Among tested cultivars 'Amazonka', 'Ambar' and 'Jet' F_1 had more satisfactory quality of fruit in the course of three–year study, regarding their storage in 2006 and 2007, while in 2008 'Pyza' also proved to possess this property. These data are in agreement with Iacuzzo and Dalla Costa [16]. According to these authors fruit decaying process during storage is a consequence of cultivar and weather conditions during pumpkin cultivation.

Conclusions

1. Cultivars of *Cucurbita maxima* featured higher content of carotenoids, vitamin C, starch, soluble solids, dry matter, total and reducing sugars than cultivars belonging to *Cucurbita pepo*.

2. Among tested cultivars 'Amazonka' and 'Ambar' were the richest source of carotenoids, vitamin C, starch, soluble solids and dry matter.

3. Differences in the level of total phenolic compounds in pumpkin fruit of all the cultivars assessed were less visible than in the case of carotenoids, vitamin C and starch contents.

4. After 90 days of storage contents of carotenoids, vitamin C, starch, total and reducing sugars, dry matter and nitrates as well as pH value decreased and the level of potassium, phosphorus, magnesium and calcium increased, whereas level of soluble solids was rather stable.

5. There was not observed significant decrease in total phenolics content in fruits of *C. maxima* and *C. pepo* after storage.

References

[1] Kunachowicz H., Nadolna J., Iwanow K. and Przygoda B.: Wartość odżywcza wybranych produktów spożywczych i typowych potraw. PZWL, Warszawa 1997, (in Polish).
[2] USDA National Nutrient Database for Standard Reference, Release 19, 2006. http://www.nal.usda.gov/fnic/foodcomp
[3] Gliemmo M.F., Latorre M.E., Gershenson L.N. and Campos C.A.: LWT-Food Sci. Technol. 2009, **42**, 196–201.
[4] Gajewski M.: Przechowalnictwo warzyw. Wyd. SGGW, Warszawa 2001, (in Polish).
[5] Gaskell M.: Pumpkin production in California. Publication 7222, University of California 1996.
[6] Rumińska A., Suchorska K. and Węglarz Z.: Rośliny lecznicze i specjalne. SGGW AR, Warszawa 1990, (in Polish), pp. 108.
[7] Slinghart K. and Singleton V.L.: Amer. J. Enol. Vitic. 1977, **28**, 49–55.
[8] Nowosielski O.: Zasady opracowania zaleceń nawozowych w ogrodnictwie. PWRiL, Warszawa 1988, (in Polish).
[9] Sztangret J., Korzeniewska A., Horbowicz M. and Niemirowicz-Szczytt K.: Veget. Crop Res. Bull. 2004, **61**, 51–60.
[10] Gajc-Wolska J., Gajewski M., Radzanowska J., Niemirowicz-Szczytt K. and Korzeniewska A.: Veget. Crop Res. Bull. 2005, **63**, 33–44.
[11] Pauluskiene A., Danilcenko H., Jariene E., Gajewski M., Seroczyńska A., Szymczak P. and Korzeniewska A.: Veget. Crop Res. Bull. 2006, **65**, 137–144.
[12] Kahkonen M.P., Hopia A.I., Vuorela H.J., Rauha J.-P., Pihlaja K., Kujala T.S. and Heinonen M.: J. Agric. Food Chem. 1999, **47**, 3954–3962.
[13] Vinson J.A., Hap Y., Su X. and Zubik L.: J. Agric. Food Chem. 1998, **46**, 3630–3634.
[14] Głąbczyński P.: EJPAU 2006, **9**(3) http://www.ejpau.media.pl/ volume9/issue3/art-03.html
[15] Pijanowski E. and Mrożewski S.: Technologia produktów owocowych i warzywnych. PWRiL, Warszawa 1973, (in Polish).
[16] Lacuzzo F. and Dalla Costa L.: Sci. Hort. 2009, **120**(3), 330–335.
[17] Noseworthy J. and Loy B.: [in:] Proc. IXth EUCARPIA meeting on genetics and breeding of *Cucurbitaceae*, INRA, Avignon (France), May 21–24th, 2008, p. 521–528.
[18] Arvayo-Ortiz R.M., Garza-Ortega S. and Yahia F.M.: Hort. Technol. 1994, **4**, 253–255.
[19] Bycroft B.I., Corrigan V.K. and Irving D.E.: New Zealand J. Crop Hort. Sci. 1999, **27**, 265–271.
[20] Nagao A. and Dahi H.: J. Japanese Soc. Hort. Sci. 1991, **60**, 175–181.
[21] Philips G.R.: Plant Physiol. 1946, **21**, 533–541.
[22] Niewczas J., and Mitek M.: Żywność. Nauka, Technologia, Jakość 2007, **5**(54), 155–164.
[23] Burda S., Oleszek W. and Lee CY.: J. Agric. Food Chem. 1990, **38**, 945–948.

SKŁAD CHEMICZNY OWOCÓW DYNI W ZALEŻNOŚCI OD ODMIANY I PRZECHOWYWANIA

[1] Katedra Ogrodnictwa
[2] Katedra Technologii Owoców, Warzyw i Zbóż
Uniwersytet Przyrodniczy we Wrocławiu

Abstrakt: Badania przeprowadzone w latach 2006–2008 miały na celu ocenę jakości dojrzałych owoców dyni pochodzących od 6 odmian dyni olbrzymiej *Cucurbita maxima* (‘Amazonka’, ‘Ambar’, ‘Bambino’, ‘Karowita’, ‘Melonowa Żółta’, ‘Uchiki Kuri’) i 6 odmian dyni zwyczajnej *Cucurbita pepo* (‘Danka Polka’, ‘Miranda’, ‘Junona’, ‘Pyza’ i ‘Warszawska Makaronowa’ oraz ‘Jet’ F_1) przed i po przechowaniu. Oceniono zawartość karotenoidów, witaminy C, skrobi, polifenoli, ekstraktu, suchej masy, cukrów redukujących i ogółem, azotanów oraz makroelementów (P, K, Mg, Ca) w owocach bezpośrednio po zbiorze i po 90-dniowym przechowywaniu w przechowalni grawitacyjnej. Dynię uprawiano z rozsady sadzonej w pole w połowie maja, owoce zbierano w drugim tygodniu września.

Owoce odmian należących do dyni olbrzymiej zawierały więcej karotenoidów, witaminy C, skrobi, ekstraktu, suchej masy oraz cukrów ogółem i redukujących niż owoce dyni zwyczajnej. Największą zawartość karotenoidów odnotowano w częściach jadalnych odmian ‘Amazonka’ (18,40 mg · 100 g^{-1} ś.m.), ‘Ambar’ (15,49 mg · 100 g^{-1} ś.m.). Najwięcej skrobi miały owoce odmiany ‘Ambar’ (61.5 mg · 100 g^{-1} ś.m.), ‘Amazonka’ (31,3 mg · 100 g^{-1} ś.m.) i ‘Uchiki Kuri’ ((20,95 mg · 100 g^{-1} ś.m.). Różnice w zawartości polifenoli pomiędzy badanymi odmianami były mniej widoczne niż w przypadku karotenoidów, witaminy C czy skrobi. Po 90-dniowym przechowywaniu zawartość karotenoidów, witaminy C, cukrów, suchej masy i azotanów oraz wartość pH malały, podczas gdy poziom makroskładników wzrastał. Nie odnotowano znaczących zmian w zawartości polifenoli po przechowaniu.

Słowa kluczowe: gatunki dyni, odmiany, przechowanie, skład chemiczny owoców dyni

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Maria GAWĘDA[1] and Zofia NIZIOŁ-ŁUKASZEWSKA[1]

EFFECT OF LEAD CUMULATION ON BORON CONTENT IN SOME VEGETABLES

WPŁYW KUMULACJI OŁOWIU NA ZAWARTOŚĆ BORU W NIEKTÓRYCH WARZYWACH

Abstract: Six species of vegetable plants: lettuce *Lectuca sativa* L., spinach *Spinacia oleracea* L., radish *Raphanus sativus* L. subvar. *radicula* Pers., onion *Allium cepa* L. var. *cepa,* red beets *Beta vulgaris* L. and carrot *Daucus carota* L. were cultivated in pots on a substrate containing lead dosed 0, 250 and 500 mg $\cdot$ kg^{-1} d.m.

Increase of lead content in substrate caused its intensive cumulating in edible parts of the tested vegetable species. At the same time boron content increased in tissues of all analysed plants: in lettuce leaves by 9.7 % after supplying 250 mg Pb $\cdot$ kg^{-1} d.m., and by 19.8 % after supplying 500 mg Pb $\cdot$ kg^{-1} d.m., in spinach leaves by 13.8 % (only under the influence of higher dose), in radish roots by 5.1 and 24.6 %, in onion by 23.9 and 39.1 %, in beetroots by 14.9 and 41.2 % and in carrot roots by 8.6 and 24.6 %.

Keywords: lead accumulation, boron, lettuce, spinach, radish, onion, red beet, carrot

One of the undesired results of rapidly developing civilisation of the past century has been excessive amount of heavy metals in the environment. Numerous works have focused on accumulation of these metals in various plants, we also know a lot about the possibilities to prevent their intensive accumulation in plant tissues. However, far less may be said about the results of heavy metal toxicity in plants, such as disorders in mineral nutrition or changes in their metabolism. Although external symptoms of heavy metal contamination in plants appear very late, there are proofs that many changes inside their cells occur fast and are far ahead of macroscopic effects.

Changes in mineral uptake are among first plant responses to heavy metal presence in the substrate. These relationships have been relatively best known in case of lead due to heavy environmental pollution with this metal and considerable hazard it poses to humans. Nitrate(V) ion uptake [1] and sulphate ion absorption [2] decrease under the influence of lead. So, it seems that, a strong antagonism between lead and phosphorus is connected with its intense retardation in the substratum through plumbous ions [3]. In

[1] Department of Vegetable Crops and Horticulture Economics, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 52 23, email: mgaweda@bratek.ogr.ar.krakow.pl

case of some plants, lead stimulates potassium uptake [4], but in general the effect of outflow of potassium ion has been observed in result of increased cell membrane permeability [5]. There is some information about either increased calcium content in plants grown in lead polluted soils [6] or about decreased content under similar conditions [7]. Similarly, a view upon changes in magnesium content in plant tissues under lead influence is somewhat unclear [8]. Lead is an inhibitor of uptake of many microelements actively occurring as bivalent cations: iron, manganese, zinc, copper and cobalt [3, 9], competing with them for active positions of carriers, enzymes or cell membranes.

Boron is a very important microelement in plant metabolism. The problem of its response to increased lead concentration in plant tissue remains unsolved. The work aimed to determine how boron content changes in edible parts of selected vegetables cultivated on substrates containing elevated lead content.

Materials and methods

A pot experiment was conducted during two growing periods in 2005 and 2006 at a Research Farm of Faculty of Horticulture, University of Agriculture in Krakow. Test materials were provided by six species of popular vegetables, each represented by two randomly chosen cultivar varieties. These comprised: lettuce *Lactuca sativa* L., 'Sonata' and 'Marysienka' cvs., spinach *Spinacia oleracea* L., 'Matador' and 'Asta' F_1 cvs., radish *Raphanus sativus* L. subvar. *radicula* Pers., 'Saxa' and 'Carmen' cvs., red beet *Beta vulgaris* L., 'Egipski' and 'Glob' F_1 cvs., carrot *Daucus carota* L., 'Kamila' F_1 and 'Kalina' F_1 cvs., and onion *Allium cepa* L. var. *cepa* Helm., 'Rawska' and 'Efekt' cvs. Substrate was prepared of rubbed highmoor peat and washed river sand. Both components are characterised by a low content of lead (below 10 mg · kg^{-1} d.m.), which places them below the upper limit of this metal natural background in Polish soils determined as 18 mg · kg^{-1} d.m. [10]. Macroelements, dosed 250 mg N, 250 mg K, 100 mg P and 60 mg Mg per a kilogram of dry matter were supplied to the substrate as chemically pure salts. Microelements were added using the microelement part of multielement MIS-4 fertilizer in the amount recommended by the producer. Acidity of the prepared substrate was decreased to pH 6.5 using chalk. Determined boron content in this substrate was ca 0.90 mg · kg^{-1} d.m. The results of basic soil analysis before experiment were given in Table 1.

Table 1

The content of macroelements, pH and salinity of the substrate

NH_4	NO_3	P	K	Ca	Mg	pH	Salinity
[mg · dm^{-3}]							[g NaCl · dm^3]
85.8	49.0	60.8	298.2	1693	164.0	6.83	1.46

The experiment was set up in the last decade of April. Mitscherlich's pots, 5 dm^3 in volume, were filled with substrate and lead added simultaneously in the form of lead acetate. Each variety was cultivated on three substrates to various degrees contaminated with lead: 0, 250 and 500 mg Pb · kg^{-1} d.m., each substrate was used per 8 pots. The pots were placed in a hotbed and seeds of spinach, radish, red beets and carrot were sown into them, and 4-week old lettuce and onion seedlings were planted. The plants were watered with distilled water up to 70 % of capillary water capacity. When the first pair of leaves appeared, eight equal plants were left per pot, except for lettuce planted three heads per pot. The vegetables were harvested at harvest maturity, thoroughly washed under running water and subsequently 25 plants per object were sampled for analysis (lettuce sample was 15 heads). Analyses were conducted on edible parts, which for individual plants were leaves, roots and bulbs.

Dry matter was assessed by drier method at 65 ^oC. Lead analysis, after plant material ashing at 450 ^oC and dissolving the remains in 10 % nitric(V) acid, was carried out by atomic absorption method [11] in Varian SpectrAA-20 spectrophotometer in acetylene--air flame. Boron was determined by colorimetric curcumin method [12] after plant mineralisation at 550 ^oC and ash dissolution in 0.1 mol · dm^{-3} HCl.

Results were statistically elaborated by analysis of variance in a fully randomised design using t-Student test at significance level 0.05. Due to tendencies recurrent in subsequent years and to simplify the result presentation, means for two years were given in the Tables.

Results

Increasing lead content in the substrate caused a raise in lead cumulation by all tested vegetable species (Table 1). Mean Pb content in lettuce leaves cultivated on a control substrate was 10.45 mg · kg^{-1} d.m. It raised by ca 102 % under the influence of 250 mg Pb · kg^{-1} d.m. dose and in result of 500 mg Pb · kg^{-1} d.m. increased by ca 135 % of the initial content.

Table 2

Lead content [mg · kg^{-1} d.m.] in edible parts of vegetables cultivated on substrate with diversified Pb content

Pb addition [mg · kg^{-1} d.m. substrate]	Lettuce		Mean for Pb addition
	Sonata	Marysienka	
0	5.75 a*	15.15 b	10.45 a
250	17.52 c	24.68 e	21.10 b
500	21.05 d	28.00 f	24.52 c
Mean for cultivar variety	14.78 a	22.61 b	
Pb addition [mg · kg^{-1} d.m. substrate]	Spinach		
	Asta F_1	Matador	
0	9.32 a	17.85 b	13.59 a
250	26.02 c	31.82 d	28 92 b
500	33.76 d	42.20 e	37.98 c
Mean for cultivar variety	23.04 a	30 62 b	

Table 2 contd.

Pb addition [mg · kg^{-1} d.m. substrate]	Radish		
	Carmen	Saxa	
0	7.90 a	6.40 a	7.15 a
250	18.52 b	21.62 b	20.08 b
500	31.25 c	40.25 d	35.75 c
Mean for cultivar variety	19.22 a	22.76 a	
Pb addition [mg · kg^{-1} d.m. substrate]	Onion		
	Efekt	Rawska	
0	4.10 a	2.98 a	3.54 a
250	6.30 bc	4.80 ab	5.55 b
500	7.28 cd	8.48 d	7.88 c
Mean for cultivar variety	5.89 a	5.42 a	
Pb addition [mg · kg^{-1} d.m. substrate]	Red beets		
	Glob F_1	Egipski	
0	7.15 a	20.08 b	13.61 a
250	22.42 c	37.38 e	29.90 b
500	30.70 d	43.90 f	37.30 c
Mean for cultivar variety	20.09 a	33.78 b	
Pb addition [mg · kg^{-1} d.m. substrate]	Carrot		
	Kamila F_1	Kalina F_1	
0	4.72 a	5.52 a	5.12 a
250	22.48 b	24.65 b	23.56 b
500	38.05 c	41.32 d	39.69 c
Mean for cultivar variety	21.75 a	23.83 b	

* Values marked with the same letter within the same species and means do not differ significantly.

Mean content of lead in spinach leaves harvested from the substrate with 0 mg Pb · kg^{-1} d.m. was 13.59 mg Pb · kg^{-1} d.m. and increased by ca 113 % and by ca 180 % after application of respective lead doses. In radish roots from lead-free substrate on an average 7.15 mg · kg^{-1} d.m. of this metal was detected. Supplying subsequent doses of Pb to the substrate resulted in its increased content in radish by ca 181 % and by ca 400 % in comparison with the control material. Onion growing in "clean" substrate revealed on an average 3.54 mg Pb · kg^{-1} d.m. Following the introduction of 250 mg Pb · kg^{-1} d.m. of substrate, this metal concentration in onion increased on average by 57 %, and by 123 % when the dose was increased twice. In red beetroots cultivated on control substrate on average 13.61 mg Pb · kg^{-1} d.m. was found. Addition of 250 and 500 mg Pb · kg^{-1} d.m. of the substrate resulted in its elevated content in roots by about 120 % and 174 % in comparison with beets grown on substrate without lead addition. In carrot roots harvested from the control substrate mean Pb content of 5.12 mg · kg^{-1} d.m.

was found. After supplying subsequent lead doses to the substrate, this element level in carrots raised on average by 360 % and 675 % in comparison with roots from the substrate without Pb addition.

Analysis of boron contents in edible parts of six studied vegetable species in each case demonstrated an elevated content of this element following an increase in lead concentration in the substrate (Table 3).

Table 3

Boron content [mg · kg^{-1} d.m.] in edible parts of vegetables cultivated on substrate with diversified Pb content

Pb addition [mg · kg^{-1} d.m. substrate]	Lettuce		Mean for Pb addition
	Sonata	Marysienka	
0	22.00 a*	31.15 cd	26.58a
250	26.20 b	32.10 d	29.15b
500	28.85 c	34.80 e	31.83c
Mean for cultivar variety	25.68a	32.68b	
Pb addition [mg · kg^{-1} d.m. substrate]	Spinach		
	Asta F_1	Matador	
0	45.80 a	47.35 a	46.58 a
250	47.00 a	47.90 a	47.45 a
500	56. 70 b	49.30 a	53.00 b
Mean for cultivar variety	49.83 a	48.18 a	
Pb addition [mg · kg^{-1} d.m. substrate]	Radish		
	Carmen	Saxa	
0	29.00 b	24.65 a	26.83 a
250	31.90 c	24.50 a	28.20 b
500	38.00 d	28.85 b	33.43 c
Mean for cultivar variety	32.97 b	26.00 a	
Pb addition [mg · kg^{-1} d.m. substrate]	Onion		
	Efekt	Rawska	
0	17.35 a	18.45 a	17.90 a
250	22.25 b	22.10 b	22.18 b
500	26.00 c	23.80 bc	24.90 c
Mean for cultivar variety	21.87 a	21.45 a	
Pb addition [mg · kg^{-1} d.m. substrate]	Red beets		
	Glob F_1	Egipski	
0	20.85 a	21.70 ab	21.28 a
250	24.00 bc	24.90 c	24.45 b
500	30.50 c	29.60 d	30.05 c
Mean for cultivar variety	25.12 a	25.40 a	

Table 3 contd.

Pb addition [mg · kg^{-1} d.m. substrate]	Carrot		
	Kamila F_1	Kalina F_1	
0	22.80 a	26.65 b	24.73 a
250	24.75 ab	28.95 c	26.85 b
500	29.40 c	33.10 c	31.25 c
Mean for cultivar variety	25.65 a	29.57 b	

* Values marked with the same letter within the same species and means do not differ significantly.

In lettuce leaves from the control soil on average 26.58 mg B · kg^{-1} d.m. was assessed. After supplying 250 and 500 mg Pb · kg^{-1} d.m. to the substrate, boron content in lettuce increased by 9.7 % and 19.8 %, respectively, in comparison with lettuce grown on substrate without lead addition. In spinach leaves grown in control substrate, on average of 46.58 mg B · kg^{-1} d.m. was registered. Supplying 250 mg Pb · kg^{-1} d.m. did not cause any significant changes in spinach boron content and only in the effect of 500 mg Pb · kg^{-1} d.m. added to the substrate, boron content increased by 13.8 % in relation to the material from uncontaminated soil. In radish roots from control substrate on average 26.83 mg B · kg^{-1} d.m. was detected. This element concentration grew with increasing lead doses in the soil by 5.1 % and 24.6 %, respectively. Onion from the control substrate had on average 17.90 mg B · kg^{-1} d.m. This element level raised by an average 23.9 % in effect of 250 mg Pb · kg^{-1} d.m. dose and by 39.1 % under the influence of 500 mg Pb · kg^{-1} d.m. dose. Mean of 21.28 mg B · kg^{-1} d.m. was registered in red beets harvested from the substrate without Pb addition. The dose of 250 mg Pb · kg^{-1} d.m. added to the soil resulted in a raised boron content in beetroots by 14.9 % whereas the double dose caused a 41.2 % increase. In carrot from the control soil on average 24.73 mg B · kg^{-1} d.m. was registered. This element content was increasing with increasing lead content in the substrate by 8.6 % and 26.4 %, respectively.

Discussion

Lead supplied into the soil in doses of 250 and 500 mg · kg^{-1} d.m. produced a manifold increase in this metal cumulation by edible parts of the tested plant species. At the same time growing lead content in tissues was accompanied by increasing boron content, although the response to toxic effect of this metal depended on individual plants. The largest extension of the boron content was observed in onion and red beets, the smallest in case of leave vegetables, lettuce and spinach, was noted. Chosen cultivars of lettuce, spinach, red beets, and carrot differed in intensity of lead accumulation. About the diverse taking this metal by cultivars of the same species was written already earlier [13]. The content of boron in cultivars of three species: lettuce, radish and carrot also differed. However it was not successful to find the proportionality between the quantity of accumulation the lead and boron absorbed by plants.

As a rule lead cumulation causes bigger or smaller decrease in the content of many macro and microelements in plant cells. Some authors under such conditions observed also elevated levels of some elements, particularly potassium, calcium, phosphorus or magnesium. These observations were usually due to some specific features of plant metabolism [4] or defence mechanism [8]. Only few authors have mentioned the effect of lead on boron content in plants. Walker et al [14] determined boron in maize cultivated in pots with an addition of 125 and 250 mg Pb · kg^{-1} d.m., however they did not obtain any consistent results.

The mass of tested plants was not reduced, so growth of boron content in their tissues could not be explained by the simple condensation effect. Another hypothesis is possible. Basic mechanisms of tolerance to heavy metals, including lead, involve their detoxication on the cell wall and preventing their penetration to the protoplast [15]. A subsequent and first living structure on the way of these metals is cell membrane, whose integrity necessary for keeping a cell alive may be ensured only when all damage is quickly repaired [16]. Boron plays an important role in maintaining the proper structure of both cell wall and cell membrane. It is considered a stabiliser of pectin cell wall lattice, where it occurs in stiff polysaccharide complexes as diester with cis-diole sugar groups [17, 18], it also plays a role of regulator of apertures in cell wall [19]. Boron has a decisive share in forming membrane structure [20]. It maintains their efficiency and its deficiency changes cell membrane permeability for sugars, proteins and phosphates [17]. Boron stimulates leaf biosynthesis of glutathion, the important factor of metal detoxification, as well [21].

So, it seems possible that increase in boron uptake under conditions of lead toxicity is caused by its share in cell defensive system. Detailed studies on cell level will undoubtedly further clarify the observations presented in this work.

Conclusions

1. Lead supplied into the soil caused a raise in this metal accumulation by all tested vegetable species (lettuce, spinach, radish, onion, beetroots, carrot), by 57 % to 360 % under influence of 250 mg Pb · kg^{-1} d.m., and by 123 % to 675 % when the dose was increased twice to 500 mg Pb · kg^{-1} d.m.

2. After supplying Pb to the substrate, boron content increased in edible parts of vegetables by 0 % to 23.9 % after application of lower dose, and by 13.8 % to 41.2 % after application of higher one.

3. It seems possible that increase in boron uptake under conditions of lead toxicity is caused by its share in cell defensive system, but this hypothesis requires further detailed investigations.

References

[1] Burzyński M. and Grabowski A.: Acta Soc. Bot. Pol. 1984, **53**(1), 77–86.
[2] John M.K. and Van Laerhoven C.: J. Environ. Qual. 1972, **1**(2), 169–171.
[3] Gawęda M.: Zesz. Nauk. AR w Krakowie, Ser. Rozprawy 1998, **240**, 67–68.
[4] Trivedi S. and Erdei L.: Physiol. Plant. 1992, **84**, 94–100.

[5] Burzyński M.: Acta Physiol. Plant. 1987, **9**(4), 229–238.
[6] Baluk A., Kociałkowski W.Z. and Komisarek J.: Prace Nauk. IOR 1988, **30**(1–2), 173–180.
[7] Godbold D.L. and Kettner C.: J. Plant Physiol. 1991, **139**, 95–99.
[8] Antosiewicz D.M.: Environ. Exp. Bot. 1993, **33**(4), 575–589.
[9] Kannan S. and Keppel H.: Zeitsch. Naturforsch. 1976, **31**, 393–396.
[10] Kabata-Pendias A. and Pendias H.: Biogeochemia pierwiastków śladowych. PWN, Warszawa 1993, pp. 76–80.
[11] Jędrzejczak R. and Szteke B.: Roczn. PZH 1990, **41**, 223–229.
[12] Evans S. and Krahenbuhl U.: Fres. J. Anal. Chem. 1994, **349**, 454–459.
[13] Michalik B., Barański R., Żukowska E. and Gawęda M.: Acta Hort. 1995, **379**, 213–220
[14] Walker W.M., Miller J.E. and Hasset J.J.: Commun. Soil Sci. Plant Anal. 1977, **8**(1), 57–66.
[15] Wierzbicka M.: Acta Soc. Bot. Polon 1995, **64**(1), 81–90
[16] Hall I.L.: J. Exp. Bot. 2002, **53**(336), 1–11.
[17] Power P.P. and Woods W.G.: Plant Soil 1997, **193**, 1–13.
[18] Tanaka Mayuki and Fujiwara Toru.: Environ. J. Physiol. 2008, **456**, 671–677.
[19] Hu H. and Brown P.: Plant Physiol. 1994, **105**, 681–689.
[20] Brown P.H., Bellaloui N., Wimmer M.A., Bassil E.S., Ruiz J., Hu H., Pfeffer H. and Dannel F.: Plant Biol. 2002, **4**, 205–223.
[21] Ruiz J.M., Brebones G., Baghour M., Ragala L., Balakbir A. and Romero L.: Phytochemistry 1998, **48**(2), 269–272.

WPŁYW KUMULACJI OŁOWIU NA ZAWARTOŚĆ BORU W NIEKTÓRYCH WARZYWACH

Katedra Warzywnictwa z Ekonomiką Ogrodnictwa
Uniwersytet Rolniczy w Krakowie

Abstrakt: Sześć gatunków roślin warzywnych: sałatę *Lactuca sativa* L., szpinak *Spinacia oleracea* L., rzodkiewkę *Raphanus sativus* L. subvar. *radicula* Pers., cebulę *Allium cepa* L. var. *cepa*, buraki ćwikłowe *Beta vulgaris* L. i marchew *Daucus carota* L. uprawiano w wazonach na podłożu z dodatkiem ołowiu w ilości: 0, 250 i 500 mg $\cdot$ kg^{-1} s.m.

Zwiększenie zawartości ołowiu w podłożu spowodowało jego intensywną kumulację w jadalnych częściach testowanych gatunków warzyw. Równocześnie wzrosła zawartość boru w tkankach wszystkich analizowanych roślin: w liściach sałaty o 9,7 % pod wpływem dawki 250 mg Pb $\cdot$ kg^{-1} s.m. podłoża i o 19,8 % pod wpływem dawki 500 mg Pb $\cdot$ kg^{-1} s.m., w liściach szpinaku o 13,8 % (tylko pod wpływem większej dawki Pb), w zgrubieniach rzodkiewki o 5,1 i 24,6 %, w cebuli o 23,9 i 39,1 %, w korzeniach buraków o 14,9 i 41,2 %, w korzeniach marchwi o 8,6 i 24,6 % odpowiednio pod wpływem dodatku 250 i 500 mg $\cdot$ kg^{-1} s.m. podłoża.

Słowa kluczowe: kumulacja ołowiu, bor, sałata, szpinak, rzodkiewka, cebula, burak ćwikłowy, marchew

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Aleksander GONKIEWICZ[1] and Małgorzata LEJA[1]

INFLUENCE OF AUXIN NAA AND ETHEPHON ON YIELD QUALITY OF APPLE (*Malus domestica* Borkh.) 'ŠAMPION' CV.

WPŁYW AUKSYNY NAA ORAZ ETEFONU NA JAKOŚĆ PLONU JABŁONI (*Malus domestica* Borkh.) ODMIANY 'ŠAMPION'

Abstract: The experiment was carried at the Experimental Station of Garlica Murowana near Krakow in 2006 and 2008. In 2007 the experiment was not conducted due to frost damages. The objects of the experiment were fourteen-year-old apple trees 'Šampion' cv. on MM.106 rootstock. The aim of the experiment was to evaluate the influence of ethephon (2-chloroethylphosphonic acid) and auxin NAA (naphthalene acetic acid) used in two terms and concentrations on the yield and fruit quality. First treatment was carried out at the end of flowering (80 % the falling petals), second when fruitlets' diameter was 12 mm. Two concentrations: 20 and 60 mg NAA $\cdot$ dm^{-3}, and 200 and 600 mg ethephon $\cdot$ dm^{-3} were used each time. Controlled trees were not sprayed. After fruit harvest total yield with division into five classes: apple blush, flesh firmness, extract content, acidity and pH were estimated.

Experiments showed that used preparations increased the number of fruit with more than 12 cm diameter and decreased the amount of small fruit in total yield. All used combinations increased pH of fruit juice in comparison with control. Used compounds did not show clear influence on fruit juice's extract contents. Used compounds did not have influence on fruit storage ability assessed.

Keywords: auxin, NAA, ethephon

Thinning of fruitlets is an essential treatment in modern apple orchards, which can guarantee high annual yield of good quality fruit. Commonly used preparations for thinning fruitlets are ethephon (*2-chloroethylphosphonic acid*) and auxin NAA (*naphthalene acetic acid*).

The aim of the experiment was to assess the effectiveness of these preparations, depending on the applied concentration and time.

[1] Department of Pomology, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 5230, email: agonkiewicz@ar.krakow.pl

Material and methods

The experiment was carried out in the Experimental Station of Garlica Murowana near Krakow in 2006 and 2008. In 2007 the experiment was not conducted due to frost damages. The objects of the experiment were fourteen-year-old apple trees, 'Šampion' cv., on MM.106 rootstock. The study was conducted in six replications (one replication equals one tree).

The aim of the experiment was to evaluate the influence of ethephon (2-chloroethyl-phosphonic acid) and auxin NAA used in two terms and concentrations on the yield and fruit quality. First treatment was applied at the end of flowering (80 % the falling petals), and second when fruitlets' diameter was 12 mm. Two concentrations: 20 and 60 mg NAA $\cdot$ dm^{-3}, and 200 and 600 mg ethephon $\cdot$ dm^{-3} were used each time. Trees of control treatments were not sprayed.

During harvest the yield of each tree was sorted into four classes of grandiosity: 5–6, 6–7, 7–8 and above 8 cm in diameter. Fruit color was estimated visually by the percentage of fruit surface covered with blush. 25 fruit from class with diameter of 6–7, and 7–8 from each tree were evaluated. Firmness was measured on side color core blushing fruit. Total acidity of fruit juice (expressed as malic acid) and juice pH were measured in 25 fruit randomly selected from each combination. For statistical calculations the average for the whole fruit value was used. Fruit were stored in an ordinary cold for 4 months and after this period firmness, extracts content, pH and acidity of the juice were measured once again.

Results

Studies showed that there was no relation between the date of treatment and the effectiveness of preparations (Table 1).

Table 1

Percentage of incorporation of the fruit [%] depended on the date of the treatment as well as type and concentration of preparation

Specification	2006	2008
Term of treatments I	12.2 a*	5.3 a
Term of treatment II	13.9 a	5.9 a
Treatments		
Control	24.1 a	6.7 a
NAA 20 mg $\cdot$ dm^{-3}	14.3 b	6.1 a
NAA 60 mg $\cdot$ dm^{-3}	11.0 c	5.3 a
Ethefon 200 mg $\cdot$ dm^{-3}	14.3 b	5.7 a
Ethefon 600 mg $\cdot$ dm^{-3}	12.8 bc	3.6 b

Explanations: I – first treatment at the ending of flowering (80 % the falling petals), II – second treatment at 12 mm fruitlets; * Values marked with same letter do not differ significantly at $\alpha = 0.05$.

The effectiveness of treatment in the first and second term was at the same level. Both preparations showed similar effectiveness, and slight differences resulted only from applied concentration. In 2006 ethephon thinned most effectively when was used in higher concentration (600 mg dm^{-3}), however the same concentration of ethephon used in the second year of the experiment caused excessive thinning. Both products used in low concentrations showed similar efficacy. Studies showed that ethephon and auxin NAA applied in both terms increased the participation of fruit with diameter larger than 7 cm and decreased the share of fruit with diameter smaller than 7 cm in total yield (Fig. 1).

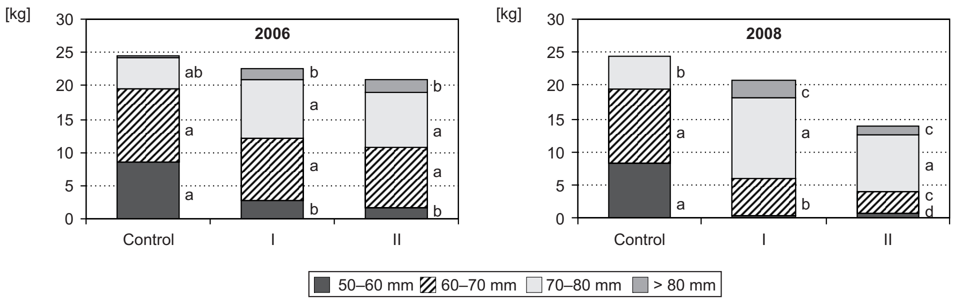

Fig. 1. Class of grandiosity in the yield of fruit in general, depending on the date of preparations application

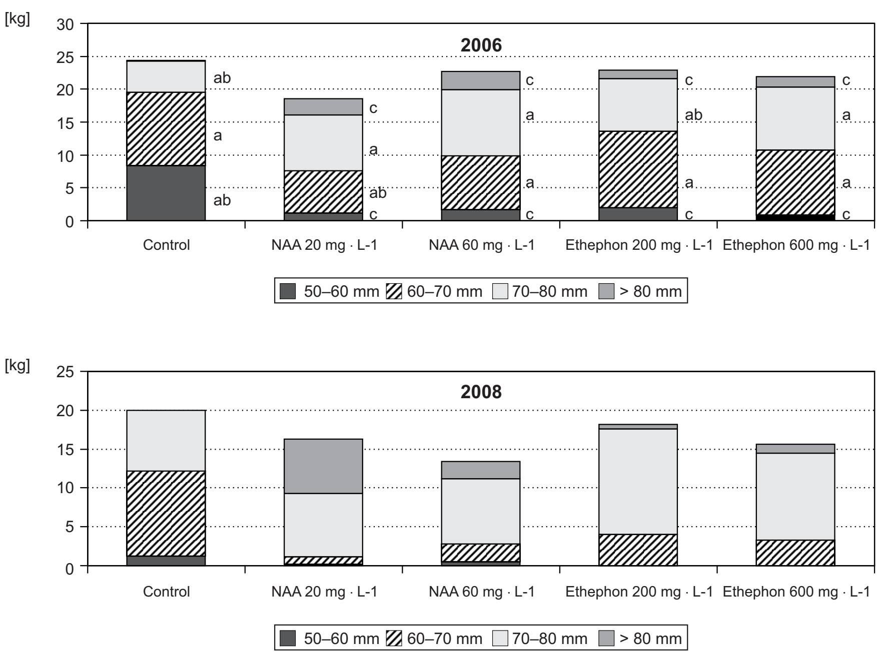

Fig. 2. Class of grandiosity in the yield of fruit in general, depending on type and concentration of applied preparation

Analyzing the effectiveness of treatments for type of preparation and concentration, there was no apparent difference between them. Both applied preparations influenced on reducing the proportion of fruit with a diameter of less than 7 cm and increasing the number of fruit over 7 cm in diameter (Fig. 2).

High concentrations of applied preparations did not cause the decrease in yield and did not affect the degree of fruit colouring. The term of treatment nor the type or concentration of used preparations did not affect the percentage of skin surface covered with apple bloom (Table 2).

Table 2

Fruit colour [%] depending on the date of the treatment as well as type and concentration of preparation

Specification	2006	2008
Term of treatment I	53.4 a*	45.9 a
Term of treatment II	52.1 a	44.9 a
Treatments		
Control	50.5 a	42.5 a
NAA 20 mg · dm^{-3}	55.0 a	42.9 a
NAA 60 mg · dm^{-3}	54.1 a	44.4 a
Ethefon 200 mg · dm^{-3}	51.4 a	49.0 a
Ethefon 600 mg · dm^{-3}	52.7 a	48.5 a

Explanations: see Table 1.

No influence of treatments was shown on the fruit firmness. Regardless of the date of treatment, type of preparation and concentration obtained results were not different from control objects (Table 3).

Table 3

Firmness of the fruit [kG] depending on the date of the treatment as well as type and concentration of preparation

Specification	2006				2008			
Term of estimation	At harvest		After storage		At harvest		After storage	
Diameter of fruit	6–7 cm	7–8 cm	6–7 cm	7–8 cm	6–7 cm	7–8 cm	6–7 cm	7–8 cm
Term of treatment I	6.7 a	6.6 a	4.7 a	4.5 a	5.8 a	5.6 a	4.5 a	4.3 a
Term of treatment II	6.7 a	6.6 a	4.4 a	4.3 a	5.8 a	5.4 a	4.4 a	4.3 a
Treatment								
Control	6.6 a	6.3 a	4.3 a	4.3 a	5.4 a	5.3 a	4.3 a	4.2 a
NAA 20 mg · dm^{-3}	6.7 a	6.4 a	4.4 a	4.3 a	5.9 a	5.8 a	4.5 a	4.3 a
NAA 60 mg · dm^{-3}	6.8 a	6.5 a	4.6 a	4.4 a	5.9 a	5.6 a	4.3 a	4.2 a
Ethefon 200 mg · dm^{-3}	6.8 a	6.4 a	4.8 a	4.5 a	5.8 a	5.6 a	4.4 a	4.4 a
Ethefon 600 mg · dm^{-3}	6.8 a	6.7 a	4.5 a	4.3 a	5.9 a	5.6 a	4.6 a	4.3 a

Explanations: see Table 1.

Studies carried out after storage showed that treatment did not affect fruit firmness, content of juice extract (Table 4) and pH of fruit juice (Table 5).

Table 4

Extract juice of fruit [%] at harvest and after storage

Treatment	2006		2008	
	At harvest	After storage	At harvest	After storage
Control	*12.6 a*	12.5 a	11.8 a	12.2 a
NAA 20 mg · dm^{-3}	12.3 a	12.3 a	11.7 a	11.9 a
NAA 60 mg · dm^{-3}	13.1 a	13.1 a	11.6 a	11.8 a
Ethefon 200 mg · dm^{-3}	12.5 a	12.4 a	12.0 a	12.1 a
Ethefon 600 mg · dm^{-3}	13.2 a	12.9 a	11.8 a	12.2 a

* Values marked with same letter do not differ at $\alpha = 0.05$.

Table 5

pH of fruit juice

Treatment	2006		2008	
	At harvest	After storage	At harvest	After storage
Control	3.8 a*	3.9 a	3.7 a	3.8 a
NAA 20 mg · dm^{-3}	3.8 a	3.9 a	3.7 a	3.8 a
NAA 60 mg · dm^{-3}	3.8 a	3.9 a	3.7 a	3.8 a
Ethefon 200 mg · dm^{-3}	3.8 a	3.9 a	3.7 a	3.8 a
Ethefon 600 mg · dm^{-3}	3.8 a	3.9 a	3.7 a	3.8 a

* Values marked with same letter do not differ at $\alpha = 0.05$.

No differences were found after harvest and after storage in comparison with the control treatment. Both applied preparations caused an increase of the total acidity of fruit juice, which was observed also after storage (Table 6).

Table 6

Total acidity of fruit juice [g · 100 g^{-1}] (expressed as malic acid)

Treatment	2006		2008	
	At harvest	After storage	At harvest	After storage
Control	0.24 d*	0.17 d	0.33 c	0.24 d
NAA 20 mg · dm^{-3}	0.29 c	0.20 c	0.41 b	0.32 a
NAA 60 mg · dm^{-3}	0.33 a	0.23 b	0.43 a	0.28 c
Ethefon 200 mg · dm^{-3}	0.31 b	0.23 b	0.43 a	0.32 a
Ethefon 600 mg · dm^{-3}	0.33 a	0.26 a	0.41 b	0.30 b

*Values marked with same letter do not differ at $\alpha = 0.05$.

No differences were found after harvest and after storage in comparison with the control treatment. All preparations caused an increase the total acidity of fruit juice, what was observed also after storage (Table 6).

Discussion

As reported by Dennis [1] auxin NAA was recommended for thinning mainly during flowering. However, subsequent studies have shown that NAA is well-thinner for fruitlets. In presented experiment it was found that auxin NAA is suitable both thinning at the end of flowering and about two weeks later also. Very similar to the NAA thinning effect was observed in case of ethephon. Its effectiveness did not depend on the date of application.

The results do not confirm the opinion according to which sensitivity to ethephon is starting to decrease after petals fall [2, 3]. The preparations applied in 3 times higher concentrations only slightly decreased fruit setting which was also observed in experiment conducted by Jones et al [4]. All treatments increased the average mass of fruit. Decreasing proportion of small fruit and increasing share of large fruits in whole yield was also observed. The treatment in the first term led to increase the average mass of fruit. Positive effect on fruit size, despite of poor thinning was also observed by other authors [5, 6].

In the experiment, no differences between the type of preparation and participation of each class of grandiosity of fruits in total yield were showed. Both used preparations in similar way affected the yield and fruit size. No significant differences were observed between NNA at concentration 20 and 60 mg $\cdot$ dm^{-3} as well as between ethephon in concentration at 200 and 600 mg $\cdot$ dm^{-3}. No effect of the term treatment, the type of used preparation or concentration on fruit color intensity was observed. Similar results obtained Michalski et al [6] and Pietranek et al [7]. In presented experiment slight impact of treatments on the decreasing of fruit flesh firmness was obtained, but the differences were not confirmed statistically. Similar results were obtained by Guaka et al [8] and Mcartney and Wells [9]. There was no effect of the treatment term on fruit firmness after harvest and after storage. In presented experiment applied thinning preparations did not influence the extract and pH of fruit juice. No impact on the tested parameters was also noted by Pietranek et al [7] and Basak [10]. In conducted experiment an increase of fruit juice acidity in all studied combinations were noted. Link [11] also reported the positive impact of this treatment on the acidity of the fruit juice.

Conclusions

1. Auxin NAA and ethephon showed similar effectiveness in thinning of flowers and fruitlets of apple trees.

2. The effect of using higher concentrations of the preparations did not differ significantly from the lower ones.

3. All treatments regardless of the preparation, concentration and term of application improved fruit quality.

4. There was no negative impact of treatments on the quality of fruits and the ability of fruit to storage.

References

[1] Dennis F.G.: Plant Growth Regulat. 2000, **31**, 1–6.
[2] Jones K.M., Bound S.A., Oakford M.J. and Koen T.T.: Austral. J. Exp. Agric. 1992, **32**, 503–506.
[3] Wertheim S.J.: Plant Growth Regulat. 2000, **31**, 85–100.
[4] Jones K.M., Bound S.A. and Oakford M.J.: New Zeal. J. Crop Hort. Sci. 1994, **22**, 203–207.
[5] Basak A.: Zesz. Nauk. AR Kraków 2000, **351**,189–192.
[6] Michalski P., Basak A. nad Wieniarska J.: Zesz. Nauk. AR Kraków 2000, **364**, 241–245.
[7] Pietranek A., Jadczuk E. and Basak A.: Roczn. AR Poznań 2000, **31**, 409–413.
[8] Guak S., Beulah M., Looney N. and Fuchigami L.: J. Amer. Soc. Hort. Sci. 2002, **7**, 165–170.
[9] McArtney S.J. and Wells G.W.: New Zeal. J. Crop Hort. Sci. 1995, **23**, 73–84.
[10] Basak A.: Acta Hort. 1998, **450**, 43–50.
[11] Link H.: Plant Growth Regulat. 2000, **31**, 17–26.

WPŁYW AUKSYNY NAA ORAZ ETEFONU NA JAKOŚĆ PLONU JABŁONI (*Malus domestica* Borkh.) ODMIANY ‘ŠAMPION’

Katedra Sadownictwa i Pszczelnictwa, Wydział Ogrodniczy
Uniwersytet Rolniczy w Krakowie

Abstrakt: Doświadczenie przeprowadzono w sadzie doświadczalnym w Garlicy Murowanej koło Krakowa w latach 2006 i 2008. W 2007 r. ze względu na uszkodzenia przymrozkowe nie prowadzono badań. Obiektem badań były intensywnie plonujące czternastoletnie drzewa jabłoni odmiany ‘Šampion’ na podkładce ‘MM.106’. Celem doświadczenia była ocena wpływu etefonu oraz auksyny NAA na ilość i jakość plonu. Każdy z preparatów zastosowano w dwóch stężeniach: 200 i 600 mg etefonu $\cdot$ dm^{-3} oraz 20 i 60 mg NAA $\cdot$ dm^{-3}. Zabiegi wykonano w dwóch terminach: gdy opadło 80 % płatków korony oraz gdy zawiązek z kwiatu królewskiego osiągnął 12 mm średnicy. Drzewa kontrolne nie były opryskiwane. Podczas zbioru oceniano: plon ogólny z podziałem na klasy wielkościowe, powierzchnię jabłek pokrytych rumieńcem, jędrność miąższu, ekstrakt, ogólną kwasowość soku oraz pH.

Wszystkie zastosowane zabiegi spowodowały zwiększenie udziału jabłek o średnicy powyżej 7 cm oraz zmniejszenie ilość owoców drobnych w ogólnym plonie. Stwierdzono również dodatni wpływ zastosowanych zabiegów na wzrost kwasowości soku owoców. W doświadczeniu nie stwierdzono wpływu zabiegów na stopień wybarwienia owoców oraz jędrność miąższu, pH oraz ogólną kwasowość ekstraktu soku. Zastosowane preparaty nie miały wpływu na zdolność przechowalniczą owoców.

Słowa kluczowe: auksyna, NAA, etefon

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Krzysztof KLAMKOWSKI[1], Waldemar TREDER[1]
and Anna TRYNGIEL-GAĆ[1]

GROWTH AND PHOTOSYNTHETIC ACTIVITY OF CUCUMBER AS INFLUENCED BY DIFFERENT FERTILIZATION REGIMES

WZROST ORAZ AKTYWNOŚĆ FOTOSYNTETYCZNA ROŚLIN OGÓRKA W ZALEŻNOŚCI OD ZASTOSOWANEGO NAWOŻENIA

Abstract: The investigation aimed at examining the changes in growth and photosynthetic activity of greenhouse-grown cucumber plants subjected to various fertilization regimes. The plants were subjected to the following treatments: standard fertilization with nutrient solution (control), foliar treatments with two fertilizers (complete or nitrogenous), without any fertilization (non-fertilized plants). The plants without fertilization were supplied with water only.

Lack of fertilization resulted in the reduction of net photosynthesis and leaf chlorophyll content. The lowest rates of photosynthesis and leaf chlorophyll content were observed in the non-fertilized cucumber plants. Also, retardation in plant growth was evident in this group of plants as a result of nutrient deficiency. Foliar application of complete fertilizer (Agroleaf Power Total) had a pronounced effect on photosynthesis and growth of cucumber plants. On the other hand, the plants sprayed with nitrogenous fertilizer (Basfoliar 36 Extra) assimilated with low intensity, and their vigor did not differ significantly from that recorded for plants supplied with water only (non-fertilized).

Keywords: gas exchange, plant vigor, chlorophyll content, foliar fertilization

Fertilization is an important production factor influencing quantity and quality of yield [1, 2]. The basic way of providing plants with essential nutrients is soil fertilization in which mineral elements are taken up by plant root system. However, in certain periods plants require substantially larger quantities of nutrients than available from soil. In such cases foliar nutrition with both macro- and microelements is a method of ensuring that a plant receives a balanced supply of nutrients. The advantage of foliar nutrition is its rapid effect, limitation of nutrient losses, and restriction of environmental pollution (lack of sorption or leaching).

[1] Department of Growth and Fruiting Regulation, Research Institute of Horticulture, ul. Konstytucji 3 Maja 1/3, 96–100 Skierniewice, Poland, phone: +48 46 834 5238, email: kklamk@insad.pl

Formation and the functional state of the plant assimilation apparatus depends on many factors including mineral nutrition. It was shown that carbon dioxide uptake was reduced as a consequence of limited nutrient supply in several experiments [3, 4]. Despite the significant number of investigations on fertilization requirements of cucumber [eg 5, 6], little is known about physiological characteristics of cucumber plants under nutrient deficiency conditions.

The main objectives of the study were: (i) to examine the vegetative growth and photosynthetic activity of greenhouse grown cucumber plants under conditions of low availability of nutrients; (ii) to compare the effect of two types of foliar fertilizers: 'complete fertilizer' (containing nitrogen, phosphorus, potassium and micronutrients) and 'nitrogenous fertilizer' (containing nitrogen and micronutrients) on growth and physiological condition of cucumber plants.

Materials and methods

The experiment was conducted in a greenhouse of the Research Institute of Pomology and Floriculture in Skierniewice, Poland in 2008. A cucumber (*Cucumis sativus* L.) 'Octopus' cultivar was the object of the experiment. In May 2008 seeds were planted in multicell trays (volume of one tray was 50 cm^3) filled with a mixture of sand and perlite (3:1). After sprouting, the plants were moved to pots of higher volume (1500 cm^3) filled with a mixture of sand and perlite. Climatic conditions recorded in a greenhouse chamber were as follows: temperature 16–24 ^oC during a day, 15–18 ^oC at night, relative air humidity maintained at 80 %, PAR (*photosynthetically active radiation*) irradiance minimum 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (during a cloudy day).

The following treatments were applied:

(i) standard fertilization (optimal nutrition, control) – normal fertilization used in greenhouse cucumber production systems; plants were fertigated with nutrient solution of the following content (in 1 dm^3): 0.7 mg NH_4-N, 224 mg NO_3-N, 47 mg P, 313 mg K, 170 mg Ca, 33 mg Mg, 0.84 mg Fe, 0.55 mg Mn, 0.33 mg Zn, 0.27 mg Cu, 0.048 mg B and 0.048 mg Mo [7],

(ii) plants supplied with water only during the experimental period (without any fertilization),

(iii) foliar application of 'complete fertilizer'; Agroleaf Power Total (20:20:20 + B, Cu, Fe, Mn, Zn, Mo) commercial fertilizer was used in a concentration of 1 %,

(iv) Foliar application of 'nitrogen fertilizer'; Basfoliar 36 Extra commercial fertilizer (36.6:0:0:4.3 + B, Cu, Fe, Mn, Zn, Mo) was used in a concentration of 0.55 %.

During the experimental period, the plants treated with foliar fertilizers were supplied with water only (no other fertilization was applied). Foliar application treatments were initiated in July 2008 at the beginning of a blooming stage. Two sprayings with the fertilizers were conducted at an interval of 5 days.

Five days after the first and the second foliar application (two sampling dates), an assessment of physiological status of plants from all combinations was conducted using the following methods:

1. leaf gas exchange – for evaluation of photosynthetic CO_2 assimilation rates (net photosynthesis); the gas exchange rate was measured using an LI-6400 portable photosynthesis system (LI-COR, USA),

2. intensity of leaf greenness (*chlorophyll content index*, CCI); this parameter reflects relative chlorophyll content in leaves; measurements were performed using CCM-200 (Opti-Sciences, USA) analyzer.

Assessment of plant morphology was done after finishing the experiment. Morphological characterization involved measurements of fresh and dry mass of stems and leaves, number of leaves, and total surface area of leaves. The surface area was measured using image analysis system (WinDIAS, Delta-T Devices, UK).

Each treatment combination was replicated twenty times (20 plants per treatment). All data were statistically elaborated using analysis of variance (ANOVA), followed by means separation using Duncan's multiple-range t-test at $p < 0.05$. All calculations were performed with the Statistica software package (StatSoft, USA).

Results and discussion

The gas exchange method was used to determine the photosynthetic activity of plant leaves. Changes in gas exchange rate provide a quick and non-destructive method for estimation of plant response to stress factors [8]. The photosynthetic activity of a plant depends on many factors including mineral nutrition [4, 9].

The highest rates of net photosynthesis were observed in the leaves of cucumber plants fertigated with nutrient solution (control) (Fig. 1). The intensity of photosynthesis recorded for this group of plants was about three times higher compared with the non-fertilized ones. Nutrient deficiency resulted in drastic reduction in net photosynthesis, as it was presented in case of plants supplied with water only (without any fertilization).

Positive effect of spraying with foliar fertilizers on photosynthesis intensity of cucumber plants was found. The most distinct effect was observed in plants treated with complete fertilizer (Agroleaf Power Total), which showed higher level of net photosynthesis compared with the plants sprayed with nitrogen fertilizer (Basfoliar 36 Extra) (Fig. 1). The photosynthetic rate of plants treated with complete fertilizer (measured after the second application) was more than two times higher compared with the non-fertilized plants. Analysis of photosynthesis after the first and the second foliar application revealed that in case of complete fertilizer (Agroleaf Power Total) it was more effective to use two applications (Fig. 1). Unlike this product, an increase in photosynthetic intensity was found only after the first spray with nitrogen fertilizer (Basfoliar 36 Extra). After the second application of this fertilizer net photosynthesis did not differ significantly from the level recorded for plants sprayed with water only (non-fertilized).

The reduction in photosynthetic activity of stressed plants can be attributed both to stomatal (stomatal closure) and non-stomatal (impairments of metabolic processes) factors. High nutrient availability may either increase or decrease the stomatal conductance of plants [4, 10–11]. In our study, foliar fertilization had a slight effect on

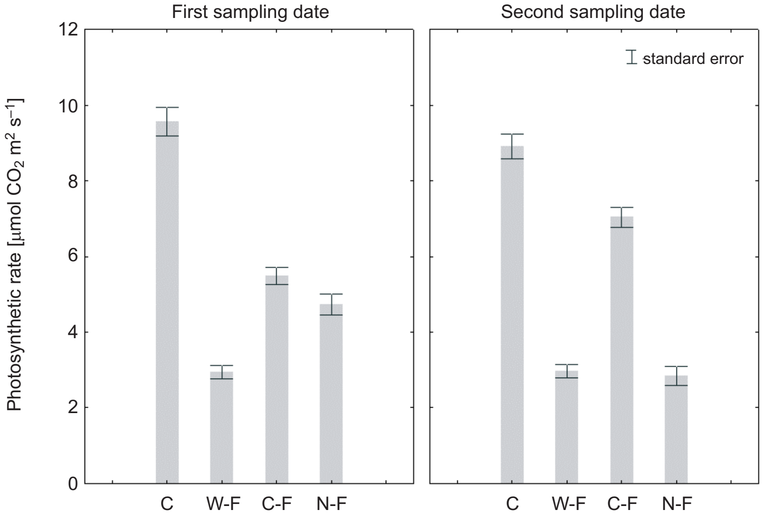

Fig. 1. Net photosynthesis in the leaves of cucumber plants as influenced by fertilization regime and term of sampling; C – control, W-F – without fertilization, C-F – complete foliar fertilizer, N-F – nitrogen foliar fertilizer

stomatal conductance [data not presented]. Thus, an increase in net photosynthesis observed in plants sprayed with complete fertilizer (Agroleaf Power Total) could be attributed to the improvement of the activity of photosynthetic enzymes. The increase in the enzyme activity due to application of mineral nutrients was noted by Siddiqui et al [12].

CCI index was used to determine the relative content of chlorophyll, which is a basic photosynthetic pigment in leaves [13, 14]. It was showed that content of photosynthetic pigments can be decreased under conditions of mineral nutrient deficiency [15, 16].

Relative chlorophyll content in cucumber leaves was diversified depending on an applied fertilization treatment. CCI was the highest in control plants (fertigated with nutrient solution). Intensity of leaf greenness in this combination was more than 4 times higher compared with non-fertilized plants (after the second application) (Fig. 2).

Among the plants treated with foliar fertilizers, higher CCI values were recorded in cucumber sprayed with complete fertilizer (Agroleaf Power Total) (Fig. 2). The increased amount of chlorophyll in leaves can explain an enhanced photosynthetic activity observed in plants treated with this fertilizer.

Changes in amount of leaf chlorophyll are often regarded as mechanism of photosynthetic acclimation to environmental factors [17]. In the present experiment, alterations in leaf chlorophyll content could be a part of a regulative system of photosynthesis to changes in plant nutritional status. An increase of chlorophyll content in leaves was recorded also in other crop species treated with different foliar fertilizers [18, 19].

Nutrient deficiency leads to reduced growth and productivity of plants [20, 21]. As photosynthesis is a major determinant of plant productivity, it was no surprise that the

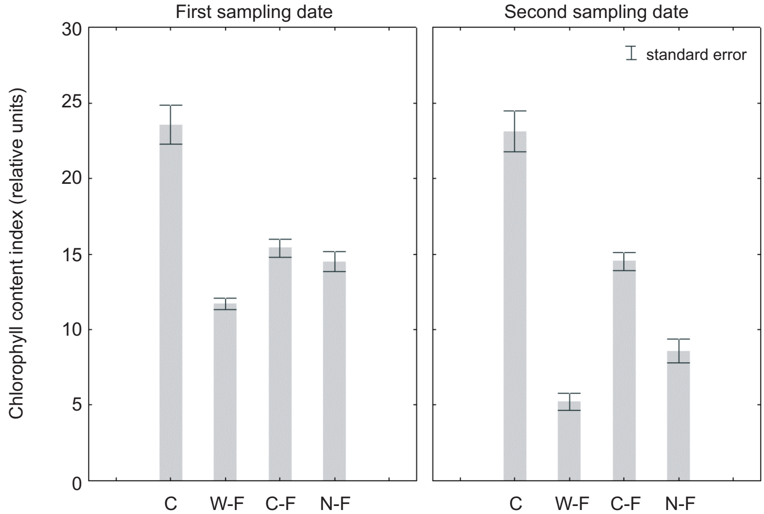

Fig. 2. Intensity of leaf greenness (CCI index) of cucumber plants as influenced by fertilization regime and term of sampling; C – control, W-F – without fertilization, C-F – complete foliar fertilizer, N-F – nitrogen foliar fertilizer

optimally fertilized (control) plants were characterized by the most intensive growth (Table 1).

Table 1

Growth related parameters of cucumber plants as influenced by fertilization regime

Treatment	Stem mass [g]		Leaf mass [g]		Number of leaves	Total leaf area [cm^2 · plant^{-1}]
	fresh	dry	fresh	dry		
Control	42.87 c	3.10 a	47.92 b	7.04 a	24.10 b	3189.44 c
Without fertilization	17.89 a	2.43 a	18.58 a	4.97 a	14.30 a	889.04 a
Complete fertilizer	31.15 b	4.25 b	42.03 b	11.43 b	23.30 b	1761.16 b
Nitrogenous fertilizer	23.28 ab	3.26 ab	22.41 a	5.59 a	16.10 a	1048.23 a

Means within the columns marked with the same letter are not significantly different (5 %) according to Duncan's multiple range-test.

Foliar application of complete fertilizer caused a significant increase in fresh weight of cucumbers stems and leaves (compared with the non-fertilized plants) (Table 1). The lowest values of these parameters were found within the combinations in which no fertilization or application of nitrogen fertilizer (Basfoliar 36 Extra) was applied. Foliar application of Agroleaf Power Total fertilizer caused increased dry matter accumulation (Table 1) indicating efficient nutrient uptake by treated plants. It was confirmed by analysis of mineral element content of plant tissue [data not presented].

Similarly to the mass, the leaf area was dependent upon the applied fertilizer. The total leaf area was the highest among the plants which were fertigated with nutrient solution (control) followed by those sprayed with Agroleaf Power Total. Plants from these two combinations were also characterized by the highest average number of leaves (Table 1).

Conclusions

Complete lack of fertilization resulted in drastic reduction in photosynthetic CO_2 assimilation and severe retardation in plant vegetative growth. The study confirmed high efficiency of complete foliar fertilizer in diminishing the negative effects of nutrient stress. It seems that in case of plants grown under conditions of low nutrient availabilities the positive impact of sprays with Agroleaf Power Total (complete fertilizer) on plant performance was related to improved nutrition. Besides trace elements, this fertilizer contains nitrogen, phosphorus and potassium. Basfoliar 36 Extra fertilizer contains nitrogen and magnesium (and trace elements). An inadequate supply of phosphorus and potassium resulted in decreased photosynthetic activity and poor vigor of the plants treated with this fertilizer.

The results also support the potential usage of non-destructive methods to characterize selected plant physiological processes. As a result of applying these methods it was possible to assess the physiological state of plants grown under nutrient stress and evaluate the efficiency of application of different foliar fertilizers.

References

[1] Jabłoński K. and Bernat E.: Progr. Plant Protect. 2001, **41**, 299–305.
[2] Chwil S. and Szewczuk C.: Acta Agrophys. 2002, **85**, 117–124.
[3] Ścibisz K. and Lenz F.: Erwerbsobstbau 1993, **35**(2), 46–49.
[4] Lima J.D., Mosquim P.R. and Da Matta F.M.: Photosynthetica 1999, **37**, 113–121.
[5] Nowosielski O., Beresniewicz A., Jaszcolt E., Mijas M., Nowosielska B., Pawlak B., Smoter J. and Szwonek E.: Acta Hortic. 1973, **27**, 166–171.
[6] Kıdoğlu F. and Gül A.: Acta Hortic. 2009, **807**, 485–490.
[7] Piróg J.: Roczn. Akad. Rol. Poznan, CCCLX, Ogrodnictwo 2004, **38**, 123–129.
[8] Bauerle W.L., Dudley J.B. and Grimes L.W.: J. Amer. Soc. Hort. Sci. 2003, **128**, 337–342.
[9] Kazda M., Salzer J., Schmid I. and von Wrangell Ph.: Plant Soil 2004, **264**(1–2), 25–34.
[10] Livingston N.J., Guy D., Sun Z.J. and Ethier G.J.: Plant, Cell Environ. 1999, **22**, 281–289.
[11] Knoll M., Achleitner D. and Redl H.: J. Plant Nutr. 2006, **29**, 1805–1817.
[12] Siddiqui M.H., Mohammad F., Khan M.N. and Khan M.M.A.: J. Plant Nutr. 2008, **31**(7), 1284–1298.
[13] Richardson A.D., Duigan S.P. and Berlyn G.P.: New Phytol. 2002, **153**, 185–194.
[14] Van den Berg A.K. and Perkins T.D.: Forest Ecol. Manage. 2004, **200**, 113–117.
[15] Suniaga Quijada J., Bonafous M. and Dumas Y.: Acta Hortic. 1992, **301**, 159–164.
[16] Nenova V.: Gen. Appl. Plant Physiol., Special Issue 2006, 81–90.
[17] Anderson J.M., Chow W.S. and Park Y.I.: Photosynth. Res. 1995, **46**, 129–139.
[18] Doroshenko T. and Alyoshin E.: Acta Hortic. 2002, **594**, 641–646.
[19] Chapagain B.P. and Wiesman Z.: Sci Hortic., 2004, **102**(2), 177–188.
[20] Del Amor F.M., Marcelis L.F.M. and Martinez V.: Acta Hortic. 2003, **614**, 535–540.
[21] Malaguti D., Rombola A.D., Quartieri M., Lucchi A., Inderst C., Marangoni B. and Tagliavini M.: Acta Hortic. 2006, **721**, 165–172.

WZROST ORAZ AKTYWNOŚĆ FOTOSYNTETYCZNA ROŚLIN OGÓRKA W ZALEŻNOŚCI OD ZASTOSOWANEGO NAWOŻENIA

Instytut Ogrodnictwa w Skierniewicach

Abstrakt: W doświadczeniu szklarniowym oceniono wzrost i aktywność fizjologiczną roślin ogórka w reakcji na zastosowane nawożenie. Kombinacje doświadczalne obejmowały rośliny nawożone dokorzeniowo (fertygacja pożywką płynną), rośliny nienawożone w trakcie trwania uprawy oraz rośliny nawożone dolistnie jednym z dwóch nawozów: wieloskładnikowym (zawierającym makro i mikroelementy) lub azotowym (zawierającym azot i mikroelementy). Rośliny nienawożone zasilane były tylko wodą.

Najmniejsze natężenie fotosyntezy i zawartość chlorofilu w liściach wykazano w przypadku roślin nienawożonych. U tej grupy roślin stwierdzono także najsilniejsze zahamowanie wzrostu. Spośród zastosowanych nawozów dolistnych, wyższą skuteczność wykazano w przypadku nawozu wieloskładnikowego. U roślin opryskiwanych tym nawozem stwierdzono większą zawartość chlorofilu w liściach oraz wysokie wartości fotosyntezy netto. Rośliny traktowane nawozem wieloskładnikowym charakteryzowały się także bardziej intensywnym wzrostem.

Słowa kluczowe: wymiana gazowa, wzrost roślin, zawartość chlorofilu, nawożenie dolistne

Vol. 18, No. 1 2011

Tomasz KLEIBER[1] and Andrzej KOMOSA[1]

EFFECT OF VEGETATION PERIOD ON THE QUANTITATIVE RELATIONS BETWEEN NUTRITIVE COMPONENTS IN THE LEAVES OF ANTHURIUM (*Anthurium cultorum* Birdsey)

WPŁYW OKRESÓW WEGETACJI NA STOSUNKI ILOŚCIOWE MIĘDZY SKŁADNIKAMI POKARMOWYMI W LIŚCIACH ANTURIUM (*Anthurium cultorum* Birdsey)

Abstract: The main objective of studies was the determination of the quantitative relations between macro- and microelements in the leaves of anthurium (*Anthurium cultorum* Birdsey) cultivars: 'Baron', 'Choco', 'Midori', 'Pistache', 'President', 'Tropical' (Anthura B.V., the Netherlands) in the spring–summer and autumn–winter periods. Plants were grown in expanded clay using drip fertigation with standard nutrient (in 1 dm^3): < 14.0 mg NH_4-N, 105.0 mg NO_3-N, 31.0 mg P, 176.0 mg K, 60.0 mg Ca, 24.0 mg Mg, 48.0 mg SO_4-S, 0.840 mg Fe, 0.160 mg Mn, 0.200 mg Zn, 0.220 mg B, 0.032 mg Cu and 0.048 mg Mo, with pH 5.5–5.7 and EC 1.5–1.8 $mS \cdot cm^{-1}$.

Significant differences were found in the quantitative amounts between some nutritive components in leaves, The leaves were fully developed, sampled from plants after freshly cut flowers. The mean N : K ratio from the last 3 years of studies in the spring–summer period was 1.0 : 2.7 and in the period of light deficit (autumn–winter period), it decreased to 1.0 : 2.4. In the same period, the relation Fe : Mn equaled 1.0 : 1.6 and with the improvement of light conditions (spring–summer period), it increased to 1.0 : 2.2. In the majority of the studied cultivars, there were significant changes in the Fe : Zn relation in autumn–winter and spring–summer periods. The awareness of changes in the qualitative relation between macro- and microelements is the basis for the modification of nutritive components in nutrients used for fertigation, depending on the vegetation period and protecting the environment against excessive quantities of used fertilizers.

Keywords: seasonal changes, plant analysis, nutrient ratio, macroelements, microelements, anthurium

Among the factors modifying the nutritive component content in plants and thereby the quantitative relations between them, one can mention the chemical composition of nutrient [1], plant age, cultivar [2] and the substrate [3, 4]. A modifying effect can be

[1] Department of Horticultural Plant Nutrition, Poznan University of Life Sciences, ul. Zgorzelecka 4, 60–198 Poznań, Poland, phone: +48 61 846 63 12, email: tkleiber@up.poznan.pl

also exerted by the vegetation period with its light conditions involved in it such as real insolation, *photosynthetic radiation* PAR, solar radiation [5, 6].

The objective of the presented studies was the cognition of the quantitative changes between the nutritive components in the indicator parts of the standard cultivars of anthurium (*Anthurium cultorum* Birdsey), depending on the vegetation period. The autumn–winter and spring–summer periods have been distinguished. Consideration of the mutual relations between the components in plants and nutrients used for fertigation permits a more precise conclusion referring to the correctness of the applied fertilization. Modification of the chemical composition of the nutrients used for fertigation, basing on the knowledge referring to the cyclicity of quantitative relations between the nutritive components in leaves permits to improve the nutrition and yielding of plants and protect the environment against excessive quantities of used fertilizers.

Material and methods

Vegetative experiments were carried out in two production farms of Wielkopolska specialized in anthurium growing. Greenhouses of "Venlo" type were equipped with modern systems of fertigation, control and recording of climatic conditions, moisture and air control, as well as energy-saving courtains. The object of studies consisted of standard anthurium cultivars (*Anthurium cultorum* Birdsey): 'Baron','Choco', 'Midori', 'Pistache', 'President' and 'Tropical' (Anthura B.V., the Netherlands) grown in expanded clay (∅ 8–18 mm). Anthurium cuttings grown in pots of rockwool (75 cm) were planted into beds in the greenhouse on the 8–11th August 2000. Studies were started on 15th January 2002 (on 2-year old plants) and they were terminated on the 30th November 2004 (4-year old plants). One growing bed with dimensions 1.2 × 46 m, covered 55.2 m^2. On 1 m^2, 14 plants were growing. Agrotechnical treatments were carried out according to the actual recommendations for anthurium.

Drip irrigation in a closed system without nutrient recirculation was applied. In the experiment, the standard nutrient for drip irrigation for anthurium grown in inert substrates was used (in 1 dm^3): < 14.0 mg NH_4-N, 105.0 mg NO_3-N, 31.0 mg P, 176.0 mg K, 60.0 mg Ca, 24.0 mg Mg, 48.0 mg SO_4-S, 0.840 mg Fe, 0.160 mg Mn, 0.200 mg Zn, 0.220 mg B, 0.032 mg Cu and 0.048 mg Mo, with pH 5.5–5.7 and EC 1.5–1.8 mS · cm^{-1} [7]. The nutrient was distributed on beds by dripping lines with emitters located in 20 cm intervals. Frequency and time of irrigation depended on the season of the year. In summer, the fertigation was applied 6–8 times supplying 4–5 dm^3 of nutrient per 1 m^2, while in winter, fertigation was applied 2–3 times using 2–3 dm^3. About 20 % of nutrient leaked out from the root zone. In order to provide an adequate air and substrate moisture, the culture was sprinkled with rain water using micro-sprinklers.

Samples of plant material were taken in the years 2002–2004 in 2-months intervals, between the 14th and the 16th day of November, January and March (autumn–winter period) and of May, July and September (spring–summer period). The indicator parts were represented by fully developed leaves, taken from plants after freshly cut flowers [8]. The leaves were randomly taken from the total surface area of beds, from plants characteristic of the given cultivar, which were healthy, well yielding and without any symptoms of damages. One average sample of a given cultivar consisted of 15–20 leaves. The method of plant material mineralization and the determination of nutritive components content was presented in the earlier papers of authors [5, 6]. Data referring to the studied vegetation periods and the light conditions related to them, ie real insolation, solar radiation (irradiation, PAR), their effect on plant yielding and on the nutrition with macro- and microelements were discussed in the earlier works [5, 6].

Statistical analyses included quantitative relations between macro- and micro-components in 3 successive years of six standard anthurium cultivars with the consideration of two vegetation periods: spring–summer and autumn–winter periods. A multidimensional analysis of variance was carried out for individual classification.

Results and discussion

Macroelements

A significant effect of vegetation periods on the change of quantitative N:K relations in the plant indicator parts have been shown. The mean relation from 3 years between N : P : K : Ca : Mg : S in the autumn–winter period was the following one: 1.0 : 0.2 : 2.4 : 1.0 : 0.2 : 0.2, while in the spring–summer period, the relations were: 1.0 : 0.2 : 2.7 : 1.0 : 0.2 : 0.2 (Table 1). Relations between N : P, N : Mg and N : S in the autumn–winter season were comparatively stable. N : K ranges were from 1.0 : 2.2 (in ‘Baron’ cultivar) to 1.0 : 2.5 (in ‘Midori’ and ‘Tropical’ cultivars).

Table 1

N : P : K : Ca : Mg : S relations in the indicator parts of anthurium in different vegetation periods

Year	Autumn–Winter Period						Spring–Summer Period					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
‘Baron’												
2002	1.0	0.2	1.8	1.4	0.1	0.2	1.0	0.2	2.2	1.2	0.1	0.2
2003	1.0	0.3	2.5	1.2	0.2	0.2	1.0	0.2	2.7	1.2	0.1	0.3
2004	1.0	0.3	2.3	0.8	0.1	0.2	1.0	0.3	2.7	1.1	0.2	0.2
Mean	1.0	0.3	2.2 a	1.1	0.1	0.2	1.0	0.2	2.5 b	1.2	0.1	0.2
‘Choco’												
2002	1.0	0.2	2.0	1.2	0.2	0.3	1.0	0.2	2.6	1.2	0.2	0.2
2003	1.0	0.3	2.5	0.9	0.1	0.2	1.0	0.2	2.7	0.9	0.1	0.2
2004	1.0	0.3	2.4	0.7	0.1	0.2	1.0	0.3	2.5	0.9	0.2	0.3
Mean	1.0	0.3	2.3	0.9	0.1	0.2	1.0	0.2	2.6	1.0	0.2	0.2
‘Midori’												
2002	1.0	0.1	2.3	1.4	0.2	0.3	1.0	0.1	2.7	1.1	0.2	0.3
2003	1.0	0.2	2.7	1.0	0.2	0.3	1.0	0.2	3.1	1.0	0.1	0.3
2004	1.0	0.3	2.6	0.6	0.2	0.2	1.0	0.3	3.3	1.0	0.2	0.3
Mean	1.0	0.2	2.5 a	1.0	0.2	0.3	1.0	0.2	3.0 b	1.0	0.2	0.3

Table 1 contd.

Year	Autumn–Winter Period						Spring–Summer Period					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
‘Pistache’												
2002	1.0	0.1	1.9	1.2	0.2	0.2	1.0	0.1	2.4	1.1	0.2	0.2
2003	1.0	0.3	2.6	0.9	0.2	0.2	1.0	0.2	3.0	1.0	0.2	0.2
2004	1.0	0.3	2.6	0.7	0.2	0.2	1.0	0.3	2.7	0.9	0.2	0.2
Mean	1.0	0.3	2.4	0.9	0.2	0.2	1.0	0.2	2.7	1.0	0.2	0.2
‘President’												
2002	1.0	0.2	2.2	1.4	0.2	0.1	1.0	0.2	2.6	1.2	0.2	0.2
2003	1.0	0.3	2.7	1.1	0.2	0.2	1.0	0.2	2.8	1.2	0.2	0.2
2004	1.0	0.3	2.4	0.9	0.2	0.1	1.0	0.3	2.6	1.0	0.2	0.2
Mean	1.0	0.3	2.4	1.1	0.2	0.1	1.0	0.2	2.7	1.1	0.2	0.2
‘Tropical’												
2002	1.0	0.2	2.2	1.2	0.2	0.2	1.0	0.2	2.7	1.1	0.2	0.2
2003	1.0	0.3	2.8	1.1	0.2	0.2	1.0	0.3	3.0	1.0	0.1	0.2
2004	1.0	0.3	2.6	0.8	0.2	0.2	1.0	0.3	3.0	0.9	0.2	0.2
Mean	1.0	0.3	2.5 a	1.0	0.2	0.2	1.0	0.3	2.9 b	1.0	0.2	0.2
Mean												
2002	1.0	0.2	2.1	1.3	0.2	0.2	1.0	0.2	2.5	1.2	0.2	0.2
2003	1.0	0.2	2.6	1.0	0.2	0.2	1.0	0.2	2.8	1.0	0.1	0.2
2004	1.0	0.3	2.5	0.8	0.2	0.2	1.0	0.3	2.7	1.0	0.2	0.2
Mean	1.0	0.2	2.4 a	1.0	0.2	0.2	1.0	0.2	2.7 b	1.0	0.2	0.2

Significant changes in N : K relations were shown in the autumn–winter period, in comparison with the spring–summer period for the cultivars: ‘Baron’, ‘Midori’ and ‘Tropical’. With the improvement of light conditions there increased the N : K relation for the mean value from the studied cultivars, from 1.0 : 2.4 (in the autumn–winter period) to 1.0 : 2.7 (in the spring–summer period).

Table 2

Mutual relations between N : P : K : Ca : Mg : S in the indicator parts of anthurium according to different authors (in each case, the accepted N content is 1.0)

Author	N	P	K	Ca	Mg	S
De Kreij et al [8][a]	1.0	0.1	1.7	0.7	0.2	—
Higaki et al [9][b]	1.0	0.1	1.1	0.6	0.2	0.1
Sonneveld and Vogt [4][c]	1.0	0.1	1.7	0.5	0.2	0.1
Mills and Scoggins [2][d]	1.0[e]	0.1	0.9	0.4	0.2	—
Mills and Scoggins [2][d]	1.0[f]	0.2	1.0	0.7	0.3	—

a – leaves from plants after freshly cut flowers, traditional cultivation; b – traditional cultivation; c – young fully developed leaves of ‘Tropical’ and ‘Cuba’ cultivars, polyphenolic foam; d – cultivation in volcanic slag; e – young leaves in 90 % mature, pale green, 10 days before full maturity; f – mature leaves, dark green with a growing in 3/4 mature flower; e–f: – cultivars: ‘Kaumana’, ‘Kozohara’, ‘Nitta Orange’, ‘Ozaki’.

The determined relations between the nutritive components were compared with data reported by other authors (Table 2). It was found that mutual N : P and N : Mg relations were similar to those reported earlier [2, 8], while in case of N : S as reported by other authors [4, 9]. The determined N : K relation (which in the autumn–winter period showed 1.0 : 2.4 and in the spring–summer period changed to 1.0 : 2.7) was higher than in the studies of other scientists. There was reported that a significant effect on the relations between macroelements in plants were exerted by the chemical composition of the applied nutrient [1].

Microelements

It was shown that vegetation periods exert an effect on the change in the quantitative relations between Fe : Mn : Zn : Cu : B in the indicator parts of anthurium (Table 3).

Table 3

Fe : Ma : Zn : Cu : B relations in the indicator parts of anthuriu min different vegetation periods

Year	Autumn–Winter					Spring–Summer				
	Fe	Mn	Zn	Cu	B	Fe	Mn	Zn	Cu	B
‘Baron’										
2002	1.0	1.2	0.9	0.1	1.2	1.0	1.9	1.3	0.1	1.2
2003	1.0	1.6	0.8	0.1	1.3	1.0	1.6	1.0	0.1	1.2
2004	1.0	2.5	0.8	0.1	1.4	1.0	1.9	1.3	0.1	1.0
Mean	1.0	1.8	0.8 a	0.1	1.3	1.0	1.8	1.2 b	0.1	1.1
‘Choco’										
2002	1.0	2.0	1.8	0.2	1.7	1.0	2.4	2.0	0.2	1.5
2003	1.0	2.1	1.3	0.1	1.8	1.0	2.6	1.4	0.2	2.1
2004	1.0	1.8	1.3	0.1	1.7	1.0	1.3	1.2	0.1	1.2
Mean	1.0	2.0	1.5	0.1	1.7	1.0	2.1	1.5	0.2	1.6
‘Midori’										
2002	1.0	2.1	1.6	0.1	1.3	1.0	3.5	2.4	0.2	2.0
2003	1.0	2.2	1.2	0.1	1.7	1.0	2.9	1.4	0.1	2.0
2004	1.0	1.8	1.1	0.1	1.8	1.0	3.5	1.5	0.1	1.3
Mean	1.0	2.0 a	1.3 a	0.1	1.6	1.0	3.3 b	1.8 b	0.1	1.8
‘Pistache’										
2002	1.0	2.0	1.3	0.1	1.4	1.0	1.8	1.4	0.1	1.5
2003	1.0	1.5	0.9	0.1	1.7	1.0	2.1	1.0	0.1	1.5
2004	1.0	1.3	0.7	0.1	1.3	1.0	1.2	0.9	0.1	1.2
Mean	1.0	1.6	1.0	0.1	1.5	1.0	1.7	1.1	0.1	1.4
‘President’										
2002	1.0	1.1	1.2	0.1	0.8	1.0	2.2	1.8	0.1	1.4
2003	1.0	1.2	0.9	0.1	1.1	1.0	1.9	1.1	0.1	1.7

Table 3 contd.

Year	Autumn–Winter					Spring–Summer				
	Fe	Mn	Zn	Cu	B	Fe	Mn	Zn	Cu	B
2004	1.0	1.2	1.0	0.1	1.4	1.0	1.4	1.0	0.1	1.0
Mean	1.0	1.2 a	1.0 a	0.1	1.1	1.0	1.8 b	1.3 b	0.1	1.4
‘Tropical’										
2002	1.0	0.9	1.0	0.1	0.8	1.0	2.6	1.7	0.1	1.8
2003	1.0	2.1	1.2	0.1	1.3	1.0	2.4	1.0	0.1	1.6
2004	1.0	1.6	0.9	0.1	1.2	1.0	2.1	1.1	0.1	1.0
Mean	1.0	1.5 a	1.0 a	0.1	1.1 a	1.0	2.4 b	1.3 b	0.1	1.5 b
Mean										
2002	1.0	1.5	1.2	0.1	1.1	1.0	2.4	1.7	0.2	1.6
2003	1.0	1.7	1.0	0.1	1.5	1.0	2.2	1.1	0.1	1.6
2004	1.0	1.7	1.0	0.1	1.5	1.0	1.9	1.2	0.1	1.1
Mean	1.0	1.6 a	1.1	0.1	1.4	1.0	2.2 b	1.3	0.1	1.4

The mean (from 3 years of studies) relation between microelements in the autumn–winter period was: 1.0 : 1.6 : 1.1 : 0.1 : 1.4, while in the spring–summer period, it was: 1.0 : 2.2 : 1.3 : 0.1 : 1.4. With the improvement of light conditions, there followed a significant increase of the mean Fe : Mn relation (from 1.0 : 1.6 to 1.0 : 2.2). Furthermore, for the majority of the studied cultivars, significant changes were shown in the Fe : Zn relation between the autumn–winter period and the spring–summer period. For the mean value from the studied cultivars, in the studied vegetation periods, the relations Fe : Zn, Fe : Cu and Fe : B were similar. The quantitative Fe : Mn ratios determined in our studies were similar to the literature data [2, 4, 9] (Table 4).

Table 4

Mutual relations between: Fe : Mn : Zn : Cu : B in the indicator parts of anthurium according to different authors (in each case, the accepted Fe content is 1.0)

Autor	Fe	Mn	Zn	Cu	B
De Kreij et al [8][a]	1.0	1.1	1.3	0.1	0.9
Higaki et al [9][b]	1.0	2.2	0.5	0.1	0.2
Sonneveld and Vogt [4][c]	1.0	1.4[e]	0.7	0.1	0.8
Mills and Scoggins [2][d]	1.0[f]	2.5	1.3	0.3	0.3
Mills and Scoggins [2][d]	1.0[g]	2.3	0.7	0.2	0.4

a – leaves from plants after freshly cut flower, traditional cultivation; b – traditional cultivation; c – young fully developed leaves of cultivars: ‘Tropical’ and ‘Cuba’, polyphenolic foam, d – cultivation in volcanic slag; e – ‘Cuba’ cultivar; f – young leaves, in 90 % mature, pale green, 10 days before full maturity; g – mature leaves, dark green, with a growing in 3/4 mature flower; f–g – cultivars: ‘Kaumana’, ‘Kozahara’, ‘Nitta Orange’, ‘Ozaki’.

The determined Fe : Zn relations were similar to the data reported by De Kreij et al [8] and for the mature leaves stated by Mills and Scoggins [2]. A similar Fe : Cu relation was reported by other authors [4, 8, 9]. A wider relation Fe : B (than reported in the literature) was found in anthurium leaves.

The quated relations between macroelements indicate that in leaves, there was a greater amount of potassium than of nitrogen, while such relations do not correspond with those found in the nutrient used for fertigation. In turn, in case of microelemens, there was a greater participation of Mn, Zn and B than Fe, while in the nutrients, there dominated the content of Fe. The above situation indicates that there is a need of studies referring to the optimization of nutrient, particularly in the range of the potassium and iron levels.

Modification of the chemical composition of nutrients used for fertigation basing on the knowledge of the cyclicity of changes in the relations between nutritive components in the indicator parts of plants may exert a positive effect on the yielding of production crops.

Conclusions

1. A significant effect of vegetation seasons was found to be exerted on the change in the quantitative N : K relations in plant indicator parts. In the spring–summer period, the N : K relation was 1.0 : 2.7, while in the autumn–winter period, it was 1.0 : 2.4.

2. With the aging of plants, in the 3-year period of studies, a decrease of the N : Ca relation was found in the plant indicator parts. In the spring–summer period, the N : Ca relation showing 1.0 : 1.3 decreased to 1.0 : 0.8, while in the autumn–winter period, it decreased from 1.0 : 1.2 to 1.0 : 0.9.

3. With the deterioration of light conditions, the Fe : Mn relation in plant indicator parts decreased from 1.0 : 2.2 (in spring–summer period) to 1.0 : 1.6 (in autumn–winter period).

4. For the majority of the studied cultivars, it was found that with the deficit of light, there followed a significant decrease in the Fe : Zn relation in plant indicator parts.

5. Knowledge of the quantitative changes between nutritive components in plant indicator parts, depending on the vegetation period, gives a basis for the modification of the chemical composition of nutrients.

Acknowledgement

The Study was cofinanced by the State Committee for Scientific Research (KBN), grant No. 0381/P06/2004.

References

[1] Dufour L. and Guérin V.: Sci. Hortic. Amsterdam 2005, **105**, 269–282.
[2] Mills H.A. and Scoggins H.L.: J. Plant Nutr. 1998, **21**(1), 199–203.
[3] Cultivation Guide Anthurium: Global Know – Hool for Growers around the World Bleiswijk, Anthura B.V., The Netherlands 1998, 43.
[4] Sonneveld C. and Voogt W.: Acta Hort. 1993, **342**, 61–67.
[5] Kleiber T., Komosa A., Krzyszkowska J. and Moliński K.: Folia Horticult. 2009a, **21**(1), 81–93.
[6] Kleiber T., Komosa A., Krzyszkowska J. and Moliński K.: Folia Horticulturae 2009b, **21**(2), 3–12.

[7] Komosa A.: [in:] V Anthurium Growers Conf., ISiK Skierniewice, 12–13.04.2000, p. 24–30.
[8] De Kreij C., Sonneveld C., Warmenhoven M.G. and Straver N.: Guide values for nutrient element contents of vegetables and flowers under glass. Voedingsoplossingen glastuinbouw, 3rd ed., 1992, vol. 15, Research Station for Floriculture and Glasshouse, Naaldwijk, Research Station for Floriculture and Glasshouse Vegetables, The Netherlands 1990.
[9] Higaki T., Imamura J.S. and Paull R.E.: HortScience 1992, **27**(8), 909–912.

WPŁYW OKRESÓW WEGETACJI NA STOSUNKI ILOŚCIOWE MIĘDZY SKŁADNIKAMI POKARMOWYMI W LIŚCIACH ANTURIUM (*Anthurium cultorum* Birdsey)

Katedra Nawożenia Roślin Ogrodniczych
Uniwersytet Przyrodniczy w Poznaniu

Abstrakt: Głównym celem badań było określenie relacji ilościowych między makro- i mikroelementami w liściach anturium (*Anthurium cultorum* Birdsey) odmian: 'Baron', 'Choco', 'Midori', 'Pistache', 'President', 'Tropical' (Anthura B.V., The Netherlands) w okresie wiosenno-letnim i jesienno-zimowym. Rośliny uprawiano w keramzycie z zastosowaniem fertygacji kroplowej pożywką standardową zawierającą (w 1 dm^3): < 14,0 mg $N-NH_4$, 105,0 mg $N-NO_3$, 31,0 mg P, 176,0 mg K, 60,0 mg Ca, 24,0 mg Mg, 48,0 mg $S-SO_4$, 0,840 mg Fe, 0,160 mg Mn, 0,200 mg Zn, 0,220 mg B, 0,032 mg Cu oraz 0,048 mg Mo, o pH 5,5–5,7 i EC 1,5–1,8 $mS \cdot cm^{-1}$.

Stwierdzono istotne zmiany w relacjach ilościowych między niektórymi składnikami pokarmowymi w organa wskaźnikowych, którymi były w pełni wyrośnięte liście, pobrane z roślin po świeżo ściętym kwiecie. Średni z 3 lat badań stosunek N : K w okresie wiosenno-letnim wynosił 1,0 : 2,7, a w okresie deficytu światła (okres jesienno-zimowy) malał do 1,0 : 2,4. W tym samym okresie stosunek Fe : Mn wynosił 1,0 : 1,6, a wraz z poprawą warunków świetlnych (okres wiosenno-letni) wzrastał do 1,0 : 2,2. W większości badanych odmian zaznaczyły się istotne zmiany stosunku Fe : Zn w okresie jesienno-zimowym i wiosenno-letnim. Znajomość zmian stosunków ilościowych między makro- i mikroelementami stanowi podstawę do modyfikacji zawartości składników pokarmowych w pożywkach stosowanych do fertygacji w zależności od okresu wegetacji, chroniąc środowisko przed nadmiernym stosowaniem nawozów.

Słowa kluczowe: okresowe zmiany, analizy roślin, relacje między składnikami, makroelementy, mikroelementy, anturium

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Elżbieta KOZIK[1], Stanisława SZCZEPANIAK[2], Alicja DOMINIAK[1] and Przemysław KOZAK[1]

REACTION OF CORSICAN HELLEBORE (*Helleborus argutifolius* Viv.) TO DIFFERENTIATED NITROGEN FERTILIZATION

REAKCJA CIEMIERNIKA KORSYKAŃSKIEGO (*Helleborus argutifolius* Viv.) NA ZRÓŻNICOWANE NAWOŻENIE AZOTEM

Abstract: The effect of differentiated nitrogen fertilization on the growth and flowering of 1-year and 2-year old plants of Corsican hellebore grown in pots in a greenhouse were defined. The applied substrate consisted of highmoor peat mixed with mineral soil (1:1). In the first year of studies, the plants were cultivated in pots of 1 dm^3 volume, while in the second year – the plants were grown in pots of 2 dm^3 volume. In both years, nitrogen fertilization was used in 4 doses and the fertilizer was applied before planting followed by top-dressing.

Proper growth and flowering of Corsican hellebore was obtained when during the first year of growing a total dose of N-fertilization was 440 or 660 $mg \cdot dm^{-3}$ of substrate and in the second year it was 300 to 600 $mg \cdot dm^{-3}$ of substrate. Increasing nitrogen fertilization caused a greater influence on the plant flowering than on the vegetative growth of Corsican hellebore.

Keywords: Corsican hellebore, nitrogen fertilization, pot cultivation

Wide assortment of perennial plants proposed for growing in containers includes hellebores. They are distinguished by non-typical time of flowering (from early winter to spring), by original flowers and beautiful leathery shining evergreen leaves. The majority of studies are devoted to the propagation and forcing of white hellebore [1–4]. In scientific literature, there is no information referring to hellebore requirements in relation to the substrate and fertilization. Szczepaniak et al [5] determined the optimal dose of calcium carbonate and the concentration of multicomponent fertilizer for top-dressing of the eastern hellebore. Adequate nitrogen fertilization exerts an influence

[1] Department of Horticultural Plant Fertilization, University of Life Sciences in Poznan, ul. Zgorzelecka 4, 60–198 Poznań, Poland, phone +48 61 846 6307, email: kozik@up.poznan.pl

[2] Department of Ornamental Plants, University of Life Sciences in Poznan, ul. Dąbrowskiego 159, 60–594 Poznań, Poland, phone: +48 61 848 79 37, email: jagaszcz@up.poznan.pl

on plant quality and on the profitability of their production, but it is also important because of ecological reasons. Schwenkel et al [6] called attention to the fact that excessive nitrogen fertilization increases the susceptibility of hellebores to the infection by black spot disease of leaves.

The objective of the presented studies was the determination of the effect of differentiated nitrogen fertilization on the growth and flowering of one-year and two-year old Corsican hellebore plants grown in pots.

Material and methods

Studies on Corsican hellebore (*Helleborus argutifolius* Viv.) were carried out in a greenhouse in two growing cycles: from 27 April 2006 to 22 March 2007 and from 3 April 2007 to 1 April 2008.

In the first year of growing, the material consisted of seedlings produced in Syngenta-Seeds Co. in multipallets. Plants in the phase of 3–4 leaves, 4 cm high, were planted on the 27th of April 2006 into pots of 1 dm^3 volume. The applied substrate consisted of highmoor peat from Lithuania mixed with mineral soil (light loamy sand) in voluminal proportion 1:1. The substrate was limed with $CaCO_3$ to pH 6.5, on the basis of neutralization curve. Nitrogen was applied in 4 variants, in which one part of the component was introduced into the substrate before planting and the other part – during cultivation. Before planting, the nitrogen doses: 50, 100, 150 and 250 mg $\cdot$ dm^{-3} of substrate in the form of NH_4NO_3 were applied. After two months of growing, top-dressing with nitrogen was started. It was used ten times with NH_4NO_3 solutions in the concentrations of 0.05; 0.1; 0.15 and 0.25 %, by introducing: 170, 340, 510 and 850 mg N $\cdot$ dm^{-3} of substrate, respectively. Moreover, before planting into pots application of 100 mg of phosphorus in the form of $Ca(H_2PO_4)_2 \cdot H_2O$; 200 mg of potassium in the form of K_2SO_4 and 150 mg of polychelate LS-7 per 1 dm^3 was used. The substrate was prepared for each pot individually.

In the second cycle of studies, the material consisted of plants for which, in the first year of studies, the fertilization was not differentiated. On the 3rd of April, 2007, the plants were transplanted into pots of 2 dm^3 volume filled with the same substrate as in the first cycle of studies. Nitrogen, before plantation, included the following doses: 100, 200, 300 and 400 mg N $\cdot$ dm^{-3} of substrate and additionally twice (18th July and 6th September), the following doses were applied in top-dressing: 50, 100, 150 and 200 mg N $\cdot$ dm^{-3} of substrate. The other mineral components were applied in the same amounts as in the first cycle of growing.

One combination included 16 plants as replications. In each cultivation cycle, in autumn, all plants were measured: the height of plants, the number of leaves and the yields of fresh and dry matter of aboveground part of plants were determined. In plant dry matter, after mineralization, the total content of macroelements was determined: N – by Kjeldahl method, P – by vanadomolybdate method, K, Ca – by flame photometry and Mg – by atomic adsorption method (AAS). Chemical analyses were done in the mean samples of plant material in the two replications.

In spring, plant flowering was estimated (number of buds and flowers), while in the second year of growing, also flower diameters were measured.

Results of measurement of each plant were statistically elaborated. Analysis of variance for one-factorial experiments was carried out. After the determination of significant differences, the mean values were grouped according to Duncan's test at the significance level of $\alpha = 0.05$.

Results and discussion

Grantzau [7] included hellebores to the group of perennial plants with small requirements in reference to nitrogen. On the other hand, Schwenkel et al [6] argued that in the growing of hellebores in pots, nitrogen should be used in the dose of 200 mg $N \cdot dm^{-3}$ of substrate and afterwards, top-dressing should be applied every 10 days in the form of fertilizer solutions in a concentration not exceeding 0.15 %. In our own studies, after 5 months of growing in 1 dm^3 pots, under the influence of increasing nitrogen fertilization, the young Corsican hellebores did not differ significantly in reference to their number of leaves (Table 1).

Table 1

Growth of Corsican hellebores in the first year of cultivation in pots, depending on the fertilizer dose

Nitrogen dose [$mg \cdot dm^{-3}$]	Height of plant [cm]	Number of leaves	Fresh matter [$g \cdot plant^{-1}$]	Dry matter [$g \cdot plant^{-1}$]
50 + 170* = 220	11.1 b**	8.6 a	21.0 a	5.5 a
100 + 340 = 440	11.9 b	9.3 a	31.3 b	9.2 b
150 + 510 = 660	11.2 b	9.3 a	30.9 b	9.0 b
250 + 850 = 1100	8.8 a	8.5 a	24.0 a	7.2 a

* Nitrogen amount applied in top-dressing; ** Mean values followed by the same letters do not differ significantly at $\alpha = 0.05$.

After the application of the doses from 220 to 660 mg $N \cdot dm^{-3}$, the plants reached a similar height (11.1–11.9 cm), while in the substrate which was most intensively fertilized with nitrogen (1100 $mg \cdot dm^{-3}$), the plant height was significantly lower. The fresh and dry matter weights of plants grown with the use of nitrogen doses of 440 and 660 $mg \cdot dm^{-3}$ were significantly greater, in comparison with the weights of plants grown in the substrates with the least and the most intensive nitrogen fertilization.

Nitrogen fertilization exerted an influence on the chemical composition of plants (Fig. 1).

Plants of hellebores with the highest mass contained: 1.56–1.72 % of nitrogen; 0.14–0.17 % of phosphorus; 0.48–0.50 of potassium; 2.85–2.92 % of calcium; 0.18–0.25 % of magnesium. The application of 250 mg $N \cdot dm^{-3}$ of substrate and the tenfold top-dressing with a 0.25 % solution of ammonium nitrate was connected with a significant increase of mineral components in the aboveground part of plants.

In the second year of Corsican hellebore cultivation, the total doses of nitrogen per 1 dm^3 of substrate were smaller than in the first year of studies, but the plants had for

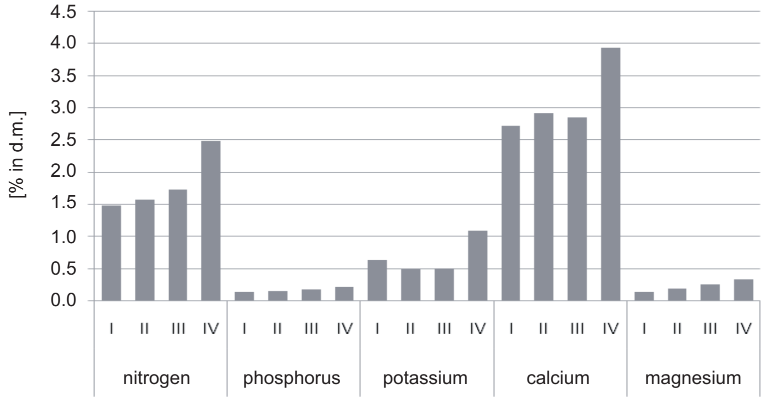

Fig. 1. Effect of nitrogen fertilization on the content of mineral components in the plants of Corsican hellebore in the first year of cultivation; Nitrogen dose [mg N · dm^{-3} of substrate]: I – 50 + 170 = 220; II – 100 + 340 = 440; III – 150 + 510 = 660; IV – 250 + 850 = 1100

their disposal a twice greater volume of substrate. No significant effect of nitrogen fertilization was found on the plant height, on the number of leaves and on fresh and dry matter of plants (Table 2).

Table 2

Growth of Corsican hellebore in the second year of cultivation in pots, depending on nitrogen doses

Nitrogen dose [mg · dm^{-3}]	Height of plant [cm]	Number of leaves	Fresh matter [g · $plant^{-1}$]	Dry matter [g · $plant^{-1}$]
100 + 50* = 150	14.0 a**	16.3 a	35.5 a	11.7 a
200 + 100 = 300	13.9 a	18.5 a	51.1 a	15.4 a
300 + 150 = 450	14.5 a	16.4 a	50.9 a	15.8 a
400 + 200 = 600	14.9 a	16.8 a	50.4 a	15.3 a

* Nitrogen amount applied in top-dressing; ** Mean values followed by the same letters do not differ significantly at $\alpha = 0.05$.

In spite of the absence of statistically confirmed differences between plants from substrates where the doses of 150–600 mg N · dm^{-3} were used, it must be stressed that the lowest fresh and dry matter content was shown by plants fertilized with the dose of 150 mg N · dm^{-3}.

Increased N doses in the substrate caused an increase in the contents of nitrogen, phosphorus, calcium, magnesium but a decrease in the potassium content in the plants of hellebore (Fig. 2).

The contents of macroelements were the following ones: 0.97–1.48 % nitrogen; 0.17–0.24 % phosphorus; 0.53–0.93 % potassium; 3.42–4.65 % calcium and 0.14–0.26 % magnesium. So far, there is no information referring to the optimal contents of mineral components in the plants of hellebores. Only with some perennial plants cultivated for

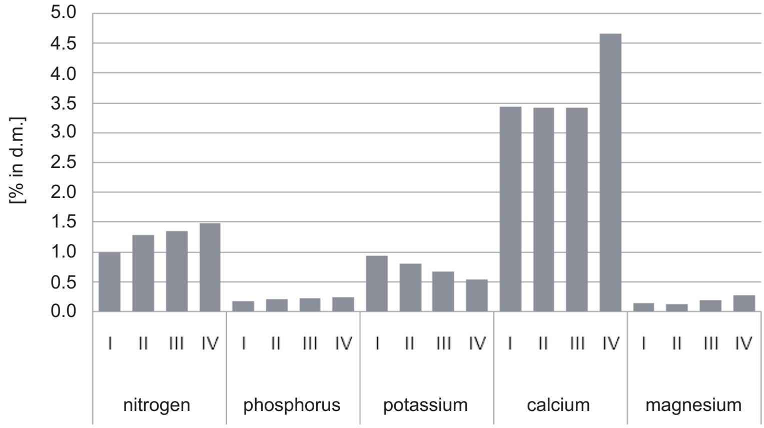

Fig. 2. Effect of nitrogen fertilization on the content of mineral components in the plants of Corsican hellebore in the second year of cultivation in pots; Nitrogen doses [mg N · dm^{-1} of substrate]: I – 50 + + 170 = 220; II – 100 + 340 = 440; III – 150 + 510 = 660; IV – 250 + 850 = 1100

cut flowers the critical contents of nitrogen and potassium in leaves were determined [8–10].

Measurements referring to the number of flowers and buds are shown in Table 3.

Table 3

Flowering Corsican hellebores grown in pots, depending on the nitrogen dose

1st year		2nd year		
Nitrogen dose [mg · dm^{-3}]	Number of buds and flowers	Nitrogen dose [mg · dm^{-3}]	Number of buds and flowers	Diameter of flowers [cm]
50 + 170* = 220	11.0 a**	100 + 50 = 150	7.9 a	5.7 a
100 + 340 = 440	15.7 b	200 + 100 = 300	22.3 b	6.3 ab
150 + 510 = 660	15.8 b	300 + 150 = 450	28.9 c	6.4 b
250 + 850 = 1100	—	400 + 200 = 600	37.5 d	6.4 b

* Nitrogen amount applied in top-dressing; ** Mean values followed by the same letters do not differ significantly at $\alpha = 0.05$.

In both years of studies, the smallest number of buds and flowers were created by plants grown in the substrate with the smallest nitrogen dose. In the first year of studies, the dose of 1100 mg N · dm^{-3} showed to be too high and it caused the dying of plants. In one-year old plants, the number of buds and flowers did not differ significantly after the application of nitrogen in the doses of 440 and 600 mg · dm^{-3}. On the other hand, the 2-year old plants showed a stronger reaction to nitrogen fertilization. With increased N doses, the number of buds and flowers was significantly larger. Plants grown in the substrate with the dose of 600 mg N · dm^{-3} flowered more abundantly, they showed about 15 buds and flowers more than plants grown in the substrate with the dose of 300 mg N · dm^{-1} of substrate. The number of buds and flowers on plants under the influence of the increasing N doses, increased from 7.9 to 37.5. Schmiemann [11] reported in her characteristics of *Helleborus argutifolius* that this species created 38 or more flowers. However, the quoted authoress did not indicate the age of plants. Zuraw and Denisow [12] called attention to the fact that the number of flowers, depending on the *Helleborus* species, may count from 28 to as many as 320 pcs on one plant. Also the flower diameter depended on the dose of nitrogen (Table 3). Flowers of plants cultivated in the substrate with the dose of 150 mg N $\cdot$ dm^{-3} were significantly smaller than the flowers grown in the substrate with the doses of 450 and 600 mg N $\cdot$ dm^{-3}. Independent of the applied N dose, the flower diameter was greater (5.7–6.4 cm) than the diameter reported by Schmiemann [11] for Corsican hellebore (5 cm).

Conclusions

1. Abundantly flowering Corsican hellebore with a high fresh matter mass can be obtained in the first year of cultivation in pots after the application of nitrogen doses from 100 to 150 mg $\cdot$ dm^{-3} of substrate followed by tenfold top-dressing with 0.1–0.15 % solution of ammonium nitrate (total 440–660 mg N $\cdot$ dm^{-3}).
2. Proper growth and flowering of Corsican hellebore can be obtained in the second year of cultivation by supplying during the whole vegetation period of 300 to 600 mg N $\cdot$ dm^{-3} of substrate.
3. Increasing nitrogen fertilization exerts a stronger influence on flowering than on the vegetative growth of Corsican hellebore.

References

[1] Pogroszewska E.: [in:] Mat. Ogólnopol. Konf. Nauk. Nauka Praktyce Ogrodniczej, AR, Lublin 1995, p. 859–862.
[2] Piskornik M., Klimek A., Lis-Krzyścin A., Gąsior A. and Krzywda A.: Zesz. Nauk. ISiK 2000, **7**, 297–301.
[3] Piskornik M.: Zesz. Probl. Post. Nauk Roln. 2002, **483**, 187–194.
[4] Piskornik M.: Acta Sci. Polon., Hortorum Cultus 2003, **2**(2), 69–74.
[5] Szczepaniak S., Henschke M., Czuchaj P. and Kozik E.: Acta Sci. Polon., Hortorum Cultus 2008, **7**(4), 13 – 22.
[6] Schwenkel H.-G., Wohanka W., Scharpf Ch., Ludolph D. and Reimherr P.: Gärtnerbörse 1998, **9**, 27–29.
[7] Grantzau E.: Dtsch. Gartenb. 2000, **8**, 40–43.
[8] Alt D.: Gartenbauwissenschaft 1978, **43**(1), 28–33.
[9] Alt D.: Gartenbauwissenschaft 1981, **46**(1), 1–8.
[10] Alt D. and Rehrmann P.: Gartenbauwissenschaft 1996, **61**(5), 219–224.
[11] Schmiemann G.: Gartenpraxis 2005, **3**, 13–18.
[12] Żuraw B. and Denisov B.: Ann. Univ. Mariae Curie-Skłodowska, Sect. EEE 2002, **10**, 45–50.

REAKCJA CIEMIERNIKA KORSYKAŃSKIEGO (*Helleborus argutifolius* Viv.) NA ZRÓŻNICOWANE NAWOŻENIE AZOTEM

[1] Katedra Nawożenia Roślin Ogrodniczych, [2] Katedra Roślin Ozdobnych
Uniwersytet Przyrodniczy w Poznaniu

Abstrakt: Określono wpływ zróżnicowanego nawożenia azotem na wzrost i kwitnienie jednorocznych i dwuletnich roślin ciemiernika korsykańskiego uprawianego w doniczkach w szklarni. Jako podłoże zastosowano torf wysoki zmieszany z glebą mineralną (1:1). W pierwszym roku rośliny uprawiano w doniczkach o pojemności 1 dm^3, a w drugim roku o pojemności 2 dm^3. W obu latach badań nawożenie azotem zróżnicowano do czterech dawek, stosując składnik przed sadzeniem roślin i pogłównie.

Prawidłowy wzrost i kwitnienie ciemiernika korsykańskiego uzyskano po dostarczeniu roślinom w ciągu całego okresu wegetacji w pierwszym roku uprawy 440 lub 660 mg $N \cdot dm^{-3}$ a w drugim od 300 do 600 mg $N \cdot dm^{-3}$ podłoża. Wzrastające nawożenie azotem silniej wpłynęło na kwitnienie niż na wzrost ciemiernika korsykańskiego.

Słowa kluczowe: ciemiernik korsykański, nawożenie azotem, uprawa w doniczkach

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Maria LEJA[1], Iwona KAMIŃSKA[1]
and Katarzyna KULCZAK[1]

ANTIOXIDATIVE PROPERTIES IN GRAPES OF SELECTED CULTIVARS GROWN IN POLAND

ANTYOKSYDACYJNE WŁAŚCIWOŚCI WINOGRON WYBRANYCH ODMIAN UPRAWIANYCH W POLSCE

Abstract: Ten grape-vine cultivars (5 white and 5 red skinned) were cultivated in south-east region of Poland. Samples were frozen and for analyzes extracts in 80 % MeOH were prepared. Contains of total phenols, phenylpropanoids, flavonols and anthocyanins were measured, using UV/VIS method. Additionally, radical scavenging activity with $DPPH^{\bullet}$ was determind.

In red skinned fruits content of phenolic compounds was higher than in white skinned ones. Cultivars showed great diversity: the highest level of phenolics was observed in 'Heridan' and the lowest in 'Bianca' cultivars.

Radical scavenging activity (RSA) was also very high in red grapes, especially in skin (over 90 % of free radical was neutralized). Antioxidant activity of white fruit cultivars was ranged between 9 and 50 % ('Bianca' and skin of 'Jutrzenka' cultivars, respectively).

In analyzed tissue correlation (r = 0.70) between total phenolics and RSA was found.

Keywords: grapes, antioxidant activity, phenolic compounds

The great number of civilization diseases can be initiated by the free radical action, particularly by the ROS (*Reactive Oxygen Species*) which are generated either during the normal cell function or are the products of environment pollution. Plant tissues are especially rich in the "defense system" against ROS, their antioxidant capacity is closely associated with activity of "free radical scavenging enzymes" (superoxide dismutase, catalase, peroxidases) and with the contents of antioxidant substances, mainly phenolic compounds, carotenoids, tocopherols and ascorbic acid [1].

High biological activity both of fresh grapes and wine produced from them is mostly due to polyphenolic substances. Jeandet et al [2] found correlation between red wine consumption and reduction of coronary heart diseases. Low mortality caused by heart

[1] Department of Plant Physiology, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 52 07, email: mleja@ogr.ar.krakow.pl; kaminskai@gmail.com

diseases among French people drinking regularly moderate amounts of red wine, despite of their high-fat diet, is called the "French paradox" as described by WHO authorities.

According to Vinson et al [3] the level of phenolics determined in grape fruits, approximately the same as in strawberries, blueberries and plums, strongly depends on grape vine species: red grapes have more phenolic compounds than the white ones. Red wine is considered as a particularly rich source of phenolics [4]. Among phenol compounds found in it the most active antioxidants are phenolic acids (gallic, gentisic, vanillic), trihydroxystilbens (cis and trans resveratrol) and flavonols (catechin, epicatechin, quercetin) [5]. Resveratrol, identified during the last years seems to be especially important in human diet as regulator of lipid metabolism [6] as well as a bacteriostatic and anticancerogenic agent [7]. The same phenolic substances were observed in fresh fruits, particularly in the red ones, however, antioxidant activity measured in fruit extracts was slightly lower in comparison with wines obtained from them. Content of total phenols, flavonols and anthocyanins was estimated in various parts of fruits of popular in Italy cultivar Negro Amaro: the highest level of flavonols was observed in seeds while that of anthocyanins was found in the skin [8].

The aim of the present study was to evaluate antioxidative ability of ten selected vine cultivars, grown in Poland. Total polyphenolics, cinnamic acid derivatives, flavonols and anthocyanins were estimated in different parts of fruits. Additionally *radical scavenging activity* (RSA) was measured.

Material and methods

The experiment was carried out in 2006–2007. The grape fruits were collected in the Golesz vineyard situated in south-east Poland, in Jaslo environment. Ten grape-vine cultivars, five white and five red skinned, mostly cultivated in Polish climate conditions, were taken for the experiment (Table 1).

Fruits were harvested in the second half of September 2006, their technological maturity was estimated by refractometric measurement of sugar level and by determination of titration acidity, expressed as the tartaric acid content.

For laboratory analyses three randomly chosen samples of fruits from each cultivar were taken. Fruits were divided into skin and flesh + skin (after the removing of seeds), in fruits of four selected cultivars flesh + skin together with seeds was analyzed. For the determination of phenolic compounds and radical scavenging activity (RSA) 2.5 g samples were frozen and kept at –20 ^{o}C until analyzed.

Tissue extracts in 80 % methanol were prepared and used for all measurements.

Determination of total phenols, phenylpropanoids (derivatives of cinnamic acid) and anthocyanins was based on UV/VIS spectrum measurements, according to the method of Fukumoto et al [9].

Radical scavenging activity was detected with DPPH$^{\bullet}$ (*1,1-diphenyl-2-picrylhydrazyl*) described by Pekkarinen et al [10]. In these methods the stable free radical is neutralized by antioxidants present in tissue extracts and the decrease of absorbance is measured. RSA is expressed as percent of free radical neutralized for 5 minutes.

The obtained results were statistically verified by two factor analysis of variance, using Duncan's test for the significance level p = 0.05.

Results

According to the presented data (Table 1) content of total phenolics was considerably higher in red fruits in comparison with the white ones. These compounds determined in the skin and in flesh + skin of white grapes did not differ significantly, while in the skin of red fruits their concentration distinctly exceeded level of flesh + skin.

Table 1

Analyzed antioxidant parameters

Grape	Cultivar	Part of fruit	DPPH neutralization [%]	Phenolic compounds [mg · 100 g^{-1} f.m.]			
				Total phenols	Phenyl-propanoids	Flavonols	Antho-cyanins
White skinned fruit	Muskat Odeski	F + S*	26.0 ± 2.3	130.0 ± 6.4	29.3 ± 1.9	36.0 ± 2.1	8.3 ± 0.3
		S	41.0 ± 2.5	183.7 ± 9.8	45.0 ± 3.2	70.0 ± 8.2	8.7 ± 0.9
	Hibernal	F + S	11.6 ± 0.4	63.0 ± 2.0	12.0 ± 0.0	13.5 ± 0.5	3.5 ± 0.5
		S	30.7 ± 0.9	108.7 ± 0.9	24.0 ± 0.6	41.7 ± 2.0	7.0 ± 0.0
	Seyval Blanc	F + S	8.3 ± 2.0	40.5 ± 1.5	7.5 ± 0.5	7.0 ± 0.0	3.0 ± 0.0
		S	34.4 ± 1.9	106.7 ± 15.3	15.3 ± 0.9	20.0 ± 2.5	6.3 ± 0.9
	Jutrzenka	F + S	19.2 ± 1.3	86.3 ± 4.3	19.7 ± 0.3	21.0 ± 1.2	5.7 ± 0.3
		S	28.7 ± 1.1	133.0 ± 7.4	29.0 ± 2.6	46.0 ± 5.2	8.0 ± 0.6
	Bianca	F + S	9.2 ± 0.4	40.7 ± 1.5	6.7 ± 0.3	6.7 ± 0.3	2.3 ± 0.3
		S	15.6 ± 1.7	79.0 ± 4.6	15.7 ± 1.5	22.7 ± 2.3	5.3 ± 0.3
		W**	91.8 ± 0.2	440.0 ± 16.7	18.0 ± 0.6	16.3 ± 0.7	10.3 ± 0.3
Red skinned fruit	Marechal Foch	F + S	41.8 ± 1.3	306.3 ± 27.2	31.3 ± 1.8	29.0 ± 2.1	138.7 ± 8.4
		S	84.1 ± 0.9	668.7 ± 28.3	61.0 ± 3.1	68.7 ± 3.4	295.3 ± 11.3
		W	84.5 ± 1.0	557.0 ± 27.5	35.3 ± 2.3	35.7 ± 1.7	133.0 ± 2.5
	Frontenac	F + S	61.2 ± 0.7	484.0 ± 24.3	35.0 ± 4.0	45.0 ± 2.6	230.3 ± 7.8
		S	85.4 ± 0.4	2065.0 ± 37.2	156.0 ± 3.2	202.0 ± 4.4	976.7 ± 11.7
		W	78.8 ± 0.9	1309.0 ± 60.0	271.7 ± 11.6	94.7 ± 2.3	531.7 ± 16.9
	Heridan	F + S	65.9 ± 0.6	570.3 ± 7.9	51.7 ± 4.1	63.0 ± 4.4	273.7 ± 13.9
		S	79.0 ± 0.3	2034.0 ± 2.6	178.0 ± 2.1	234.7 ± 1.5	986.3 ± 6.9
		W	87.6 ± 0.9	855.3 ± 38.2	62.7 ± 2.9	75.7 ± 7.4	281.0 ± 8.7
	Rondo	F + S	82.5 ± 0.2	686.7 ± 50.7	62.3 ± 3.4	77.0 ± 7.6	291.7 ± 21.7
		S	85.8 ± 0.3	1893.7 ± 125.6	137.7 ± 17.0	161.7 ± 22.4	925.7 ± 94.4
	Swenson Red	F + S	26.1 ± 0.8	117.0 ± 3.2	18.3 ± 0.7	21.3 ± 1.2	37.3 ± 1.8
		S	70.5 ± 1.7	345.7 ± 2.6	36.7 ± 0.9	56.0 ± 3.8	79.0 ± 31.0

* F – flesh; S – skin; ** W – whole fruit.

The total phenol level was strongly differentiated among cultivars (Table 1), the highest and the lowest contents were observed in ‘Heridan’ (red grapes) and in ‘Bianca’ (white grapes) cultivars, respectively.

Contents of phenylpropanoids, flavonols and anthocyanins were higher in red grapes than in the white berries, similarly, as in the case of total phenols more of these constituents were determined in the skin as compared with flesh + skin (all red and most of white cultivars) (Table 1). The great variability among cultivars was observed for all groups of phenolic compounds, the highest and the lowest contents of phenylpropanoids, flavonols and, particularly, anthocyanins were found in fruits of ‘Heridan’ and ‘Bianca’ cultivars, respectively.

In the case of whole berries (with seeds) of four cultivars (white ‘Bianca’ and red ‘Heridan’, ‘Marechal Foch’, ‘Frontenac’) the level of total phenols was significantly higher than that of either flesh + skin (all cultivars) or for skin (‘Bianca’). This dependence for phenylpropanoids, flavonols and anthocyanins was observed only in berries of ‘Frontenac’ cv. (Table 1).

Radical scavenging activity determined by DPPH method was very high and in fruits of red cultivars was much higher than in the white ones (Table 1). Similarly as in the case of phenolics, RSA in the skin exceeded that of flesh + skin.

The highest ability of free radical neutralization (over 90 %) obtained by DPPH was noticed in the skin of most of red fruits, the lowest values (about 50 %) were observed in flesh + skin of ‘Swenson Red’ cv.

In white berries the considerable variability of RSA was found, the highest and the lowest values were noticed in the skin of ‘Jutrzenka’ (50 %) and in flesh + skin of ‘Bianca’ (9 %).

In berries of white ‘Bianca’ cultivar analyzed together with seeds high RSA (91 %) measured by DPPH method exceeded markedly the value of skin and flesh + skin. In three red cultivars free radical neutralization of whole fruits was as high as RSA of skin.

Discussion

According to the presented results the great variability of antioxidative properties depended both on color of berries and on the part of fruit. For the skin of red berries the radical scavenging activity measured by DPPH method was very high and reached 90 % of the free radical neutralization while in the case of white fruits it was distinctly lower (50 %).

The main compounds responsible for high antioxidant activity in grapes are phenolics, especially anthocyanins [2–4, 9]. In the present study dark grapes contained more polyphenols than the white ones which was in agreement with the findings of Vinson et al [3]. The highest level of total phenols (2000 mg · 100 g^{-1} fresh mass) was observed in the skin of red grapes such as Frontenac, Heridan and Rondo and was accompanied by the high concentration of anthocyanins (over 900 mg · 100 g^{-1} fresh mass). In the skin and flesh of white berries the content of total phenolics was much lower (about 100 mg · 100 g^{-1} fresh mass) with a poor level (under 10 mg · 100 g^{-1} fresh mass) of anthocyanins.

According to Meyer et al [11] the relative antioxidant capacity of grape berries and wines is correlated with the level of anthocyanins. In the present investigations the highest correlation (r = 0.983) between total phenolics and RSA was found in white grapes (Fig. 1), for the red ones this value was medium (r = 0.590) (Fig. 2) while the correlation coefficient for all cultivars was r = 0.720, hence, phenol constituents of various structure seem to be associated with neutralization of free radicals.

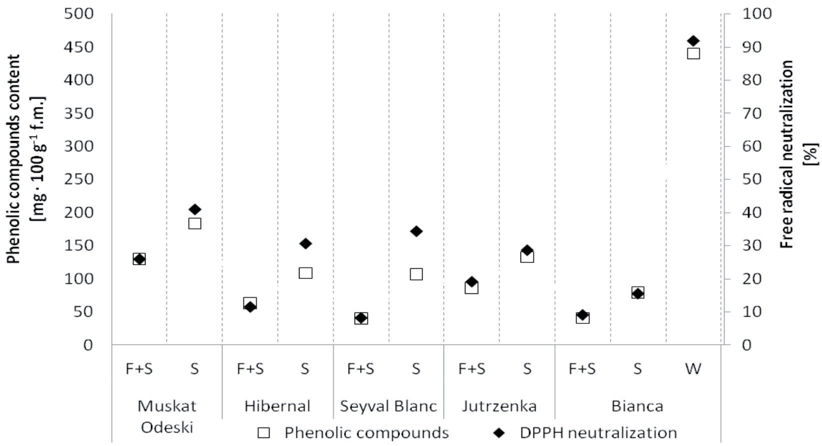

Fig. 1. Correlation between antioxidant activity and phenolics in white skinned grapes

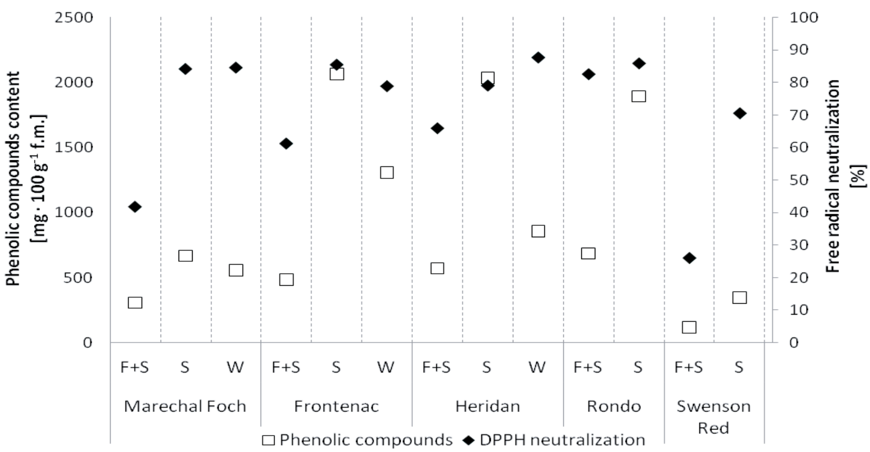

Fig. 2. Correlation between antioxidant activity and phenolics in red skinned grapes

Special attention should be paid to the analysis of whole fruits (including seeds). The antioxidant activity determined either in white ('Bianca') or in red ('Heridan', 'Marechal Foch') was very high (over 90 % of free radical neutralization). According to the above findings seeds of grape berries seemed to be a rich source of antiradical substances. Similarly, Negro et al [8] who analyzed phenolics in grape seeds found very high content (8.58 g · 100 g^{-1} dry matter) of these compounds.

In general, grape berries of all cultivars grown in Polish climate conditions are rich in health-promoting substances, particularly those of dark color, and may be recommended in the human diet.

Conclusions

1. Grape berries of cultivars grown in Poland are rich in phenolic antioxidants of various structure.
2. In dark berries the amount of phenolic substances is higher in comparison with the white ones.
3. Skin and seeds have more antioxidants than flesh tissue.
4. Radical scavenging activity is strongly correlated with level of phenolics.

References

[1] Bartosz G.: Druga twarz tlenu. PWN, Warszawa 2004.
[2] Jeandet P., Bessis R., Maume B.F., Meunnier P., Peyron D. and Trollat P.: J. Agric. Food Chem. 1995, **43**, 316–319.
[3] Vinson J.A., Su X., Zubik I. and Bose P.: J. Agric. Food Chem. 2001, **49**, 5315–5321.
[4] Sanchez-Moreno C., Larrauri J.A. and Saura-Calixto F.: Free Res. Inter. 1999, 32, 407–412.
[5] Goldberg D.M., Karumanchiri A., Ng E., Yan J., Diamandis E.P. and Soleas G.J.: J. Agric. Food Chem. 1995, **43**, 1245–1250.
[6] Waterhouse A.L.: Chem. Ind.-London 1995, **5**, 337–341.
[7] Grajek W.: Przeciwutleniacze w żywności. WNT, Warszawa 2007.
[8] Negro C., Tommasi L. and Miceli A.: Biores. Technol. 2003, **87**, 41–44.
[9] Fukumoto L.R. and Mazza G.: J. Agric. Food Chem. 2000, **48**, 3597–3604.
[10] Pekkarinen S.S., Stockmann H., Schwarz K., Heinonen M. and Hopia A.I.: J. Agric. Food Chem. 1999, **47**, 3036–3043.
[11] Meyer A.S., Yi O.-S., Person D.A., Waterhouse A.J. and Frankel E.N.: J. Agric. Food Chem. 1997, **45**, 1638–1643.

ANTYOKSYDACYJNE WŁAŚCIWOŚCI WINOGRON WYBRANYCH ODMIAN UPRAWIANYCH W POLSCE

Katedra Fizjologii Roślin, Wydział Ogrodniczy
Uniwersytet Rolniczy w Krakowie

Abstrakt: Dziesięć wybranych odmian winogron (5 o białej i 5 o czerwonej skórce) uprawiano w południowo-wschodnim regionie Polski. Z zamrożonych próbek owoców przygotowywano ekstrakty w 80 % metanolu, w których oznaczano sumę związków fenolowych, fenylopropanoidy, flawonole i antocyjany stosując metodę UV/VIS. Ponadto oznaczono zdolność neutralizowania wolnego rodnika za pomocą metody z $DPPH^{\bullet}$.

W owocach o czerwonej skórce zawartość składników fenolowych była większa niż w owocach o skórce białej. Stwierdzono znaczne zróżnicowanie odmianowe: najwyższy poziom fenoli obserwowano w odmianie Heridan, najniższy w odmianie Bianca.

Aktywność antyrodnikowa (RSA) była również bardzo duża w czerwonych winogronach, szczególnie w skórce (ponad 90 % neutralizacji wolnego rodnika). W przypadku odmian o skórce białej aktywność antyoksydacyjna była zawarta w przedziale 9–50 % (Bianca i skórka odmiany Jutrzenka).

W analizowanych tkankach stwierdzono dodatnia korelację (r = 0.70) pomiędzy sumą związków fenolowych a RSA.

Słowa kluczowe: winogrona, aktywność antyoksydacyjna, związki fenolowe

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Monika MAŁODOBRY[1], Monika BIENIASZ[1]
and Ewa DZIEDZIC[1]

YIELD STRUCTURE AND CONTENT OF SOME COMPONENTS IN FRUIT OF SIX STRAWBERRY CULTIVARS

STRUKTURA PLONU I ZAWARTOŚĆ NIEKTÓRYCH SKŁADNIKÓW W OWOCACH SZEŚCIU ODMIAN TRUSKAWKI

Abstract: Studies were conducted in the years 2002–2004 at Experimental Station of Faculty of Horticulture in Garlica Murowana near Krakow. The experiment was set up in November 2000. Six strawberry cultivars were investigated:.

Strawberry plants started yielding in year 2002. In the first year of cropping 'Elkat', 'Kent' yielded at the highest level. In year 2003 every cultivars gave the smallest yield. In the third year of cropping 'Kent' and 'Selva' cultivars showed the highest yields. For 'Elkat' and 'Senga Sengana' the highest unmarketable fruit crop was recorded. The differences in one fruit mass from the first and late crops were the biggest for 'Elkat', 'Gerida' and 'Kent' in years 2002 and 2003. For 'Gerida', 'Elsanta' and 'Kent' the highest percentage of fruit of diameter 25 mm was recorded.

Keywords: yield structure, vitamin C, anthocyanins

In Poland recently production of strawberry is the subject of some changes, in respect of number of grown cultivars. The studies on strawberry plants are conducted both in Poland and abroad [1–9]. New cultivars listed in index of cultivars every year are evaluated not only in the respect of morphological and usable features but the ability for fruit cropping as well.

Material and methods

The experiment was set up in November 2000 at the Experimental Station of Faculty of Horticulture in Garlica Murowana near Kraków. The following strawberry cultivars were the subject of experiment: 'Elkat', 'Elsanta', 'Gerida', 'Kent', 'Selva' and 'Senga

[1] Department of Pomology and Apiculture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 5229, email: mmalodobry@ogr.ar.krakow.pl

Sengana'. Young fresh strawberry plants were supplied by the Fruit Research Experimental Station in Brzezna. The experiment was carried out using the method of randomized blocks in an independent design in four replications, one replication consisted of 15 plants. The field was cover with black non-woven mulch, the plants were spaced 25 × 40 cm apart (area of one plot was 1.5 m^2). During the draught the plants were irrigated. The studies were carried out in the years 2002–2004.

The following measurements were completed: marketable yield (for 'Selva' sum of early and late crop), the yield of unmarketable fruit (ie fruit with disease symptoms, little and misshapen fruit), the mass of 100 fruits, percentage of fruit of equatorial diameter 22 and 25 mm (on the base of 100 fruits from each harvest). Following chemical analysis of fruit were performed within the fullness of time of harvesting with following methods: L-ascorbic acid content – acc. to PN-A-04019:1998, total soluble solids by refractometric measurement – acc. to PN-EN 12143:2000, pH of fruit juice by potentiometry – acc. to PN-90/A-75101/06, titratable acidity – acc. to PN-EN 12147:2000), anthocyanins – differentiated pH method calculated onto pelargonidyn-3-glucoside [10].

Results were statistically verified at using analysis of variance, the significant differences were evaluated using the Duncan test at p = 0.05.

Results and discussion

In the discussed years both total precipitation and precipitation in April, May and July was lower than ten years' value (Table 1).

Table 1

Total precipitation, mean year temperature in the years 2002–2004 and ten years' values

Year		2002	2003	2004	Ten years' values
Total precipitation [mm]		588	479	568	602
Precipitation distribution [mm]	April	42	40	23	60
	May	57	98	56	80
	July	93	39	51	101
Mean year temperature [^{o}C]		8.7	8.2	7.8	8.1

The lowest precipitation was noted in the 2003. Mean year temperature was at the similar level as many years' value.

Due to the late time of strawberry planting in October 2000 the plants did not fruit in year 2001 and the simple inflorescences were removed. The first crop of strawberry fruit was recorded in year 2002 (Table 2).

In the first year the highest crop was noted for 'Elkat' and 'Kent', while the lowest yield was recorded in Selva cultivar. The highest unmarketable fruit was obtained in 'Elkat', the other cultivars showed the similar amount of those fruit. In 2003 all the investigated cultivars gave the low crops, yet, 'Elkat' produced the most fruit. Low precipitation in that year was the reason of that fact probably (Table 1). 'Elkat' and

‘Senga Sengana’ gave the highest unmarketable fruit yield. In the third year of fruiting the highest crops were recorded for Kent and ‘Selva’. Other cultivars yielded on the same level. Similarly as in 2003, ‘Elkat’ and ‘Senga Sengana’ produced the most unmarketable fruit.

Table 2

Marketable yield and yield of unmarketable fruit of six strawberry cultivars in the years 2002–2004 (calculated per plot = 15 plants)

Cultivar/ year/ yield	2002		2003		2004		Total yield	
	marketable	unmarketable fruit	marketable	unmarketable fruit	marketable	unmarketable fruit	marketable	unmarketable fruit
	[kg]							
Elkat	6.85 b*	2.62 b	3.64 b	0.93 b	3.50 a	1.95 b	13.99 b	5.5 b
Elsanta	5.53 ab	0.47 a	1.42 a	0.18 a	3.70 a	0.60 a	10.65 a	1.25 a
Gerida	4.38 ab	0.45 a	2.59 ab	0.18 a	3.59 a	0.55 a	10.56 a	1.18 a
Kent	6.08 b	0.50 a	2.80 ab	0.23 a	5.35 b	0.76 a	14.23 b	1.49 a
Selva	3.83 a	0.55 a	1.87 a	0.23 a	4.12 ab	0.60 a	9.82 a	1.38 a
Senga Sengana	4.53 ab	1.05 a	2.64 ab	0.69 b	3.48 a	1.55 b	10.65 a	2.34 b

* Means in the columns followed by the same letters do not differ significantly at $\alpha = 0.05$.

In the discussed study the total highest crops were obtained for ‘Kent’ and ‘Elkat’ what is in agreement with the studies of other authors [3–5, 11, 12). Cultivars ‘Senga Sengana’, ‘Selva’, ‘Elsanta’ and ‘Gerida’ yielded on lower level, what is confirmed by others authors [5, 6, 9, 11, 12]. The yield of unmarketable fruit was highest in 2002, when the precipitation raised up to 93.2 mm in June. In two others years of studies ‘Elkat’ and ‘Senga Sengana’ produced the most unmarketable fruit. Many authors inform of high percentage of ‘Senga Sengana’ rotten fruit [6, 13, 14].

Cultivars differed in respect of fruit mass (Table 3).

Table 3

Mass of 100 fruit of six strawberry fruit

Cultivar	2002	2003	2004
	[kg]		
Elkat	1.25 ab	1.13 ab	1.27 ab
Elsanta	1.39 b	1.37 b	1.40 b
Gerida	1.48 b	1.35 b	1.41 b
Kent	1.30 ab	1.19 ab	1.29 ab
Selva	1.11 a	0.92 a	1.05 a
Senga Sengana	0.92 a	0.83 a	0.90 a

Explanation see Table 1.

In every year of experiment the greatest mass of fruit was noted for ‘Gerida’ and ‘Elsanta’, and the lowest one for ‘Selva’ and ‘Senga Sengana’. Also in other experiment

[6] cultivars ‘Gerida’ and ‘Elsanta’ exhibited the greatest fruit mass. Other authors [11, 12, 14] obtained slightly less fruit mass for ‘Elsanta’ and Elkat. Kopytowski et al [11] recorded greater mass for Kent fruit and similar fruit mass for ‘Senga Sengana’ comparing with the presented study. ‘Gerida’, ‘Elsanta’ and ‘Kent’ produced the most fruit of equatorial diameter 25 mm (Fig. 1).

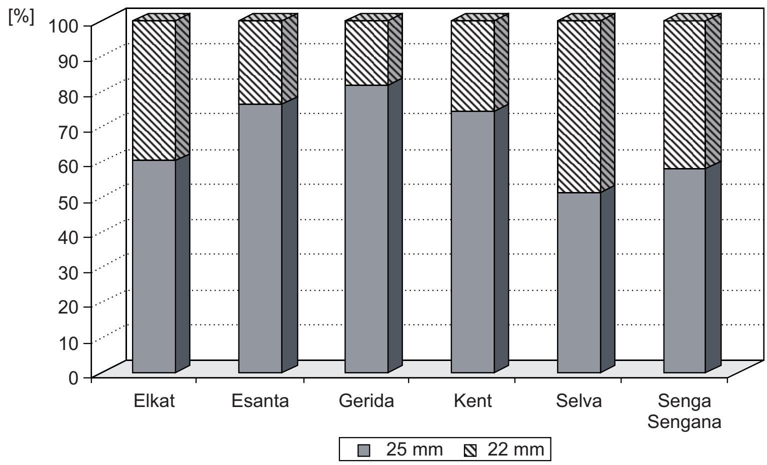

Fig. 1. Percentage of fruit recorded in two groups (22 and 25 mm fruit diameter) in marketable yield for six strawberry cultivars (mean for three years)

The results concerning L-ascorbic acid and anthocyanins content in fruit of investigated strawberry cultivars were presented in Table 4.

Table 4

L-ascorbic acid and anthocyanins content in fruit of six strawberry cultivars [mg · 100 g^{-1}]

Cultivar	2002		2003		2004	
	L-ascorbic acid	anthocyanins	L-ascorbic acid	anthocyanins	L-ascorbic acid	anthocyanins
Elkat	47.6 b	39.1 d	45.1 c	42.1 d	38.0 bc	40.5 d
Elsanta	73.5 c	13.4 a	76.1 e	13.0 a	66.1 d	14.0 a
Gerida	47.6 b	17.3 b	62.7 d	16.9 b	38.9 bc	18.4 b
Kent	44.1 a	30.1 c	41.0 b	25.5 c	25.9 a	29.7 c
Selva	48.1 b	17.5 b	29.9 a	16.9 b	41.1 c	17.9 b
Senga Sengana	48.7 b	35.3 d	51.0 c	33.7 cd	34.6 b	38.8 d

Explanation see Table 1.

In each year of study the highest content of L-ascorbic acid was recorded for fruit of ‘Elsanta’ cv., and in the fruit of other cultivars the content of that vitamin was lower. Zmuda et al [15] and Skupien [16] stated the high content of L-ascorbic acid in ‘Senga

Sengana' cv. Masny et al [17] obtained much lower content of vitamin C in 'Senga Sengana' and 'Elkat' fruit.

In the discussed study 'Senga Sengana' and 'Elkat' fruit contained the most anthocyanins. Masny et al [17] and Zmuda et al [15] obtained similar results. However, Bojarska et al [18] got the different results for 'Elsanta'.

In Table 5 the results concerning total soluble solids, pH of fruit juice and titratable acidity are presented.

Table 5

Total soluble solids, pH of fruit juice and titratable acidity

Cultivar	2002			2003			2004		
	Total soluble solids [%]	pH	Titratable acidity [g · 100 g^{-1}]	Total soluble solids [%]	pH	Titratable acidity [g · 100 g^{-1}]	Total soluble solids [%]	pH	Titratable acidity [g · 100 g^{-1}]
Elkat	5.90 a	3.53 b	0.90 b	7.89 a	3.53 a	0.88 bc	9.31 b	3.47 bc	0.94 b
Elsanta	7.63 e	3.48 b	0.85 ab	10.13 d	3.81 c	0.77 abc	9.25 b	3.51 bc	0.89 ab
Gerida	7.95 f	3.50 a	0.80 a	10.18 d	3.77 c	0.76 ab	8.91 b	3.50 bc	0.82 a
Kent	7.55 d	3.40 a	0.85 ab	11.03 e	3.82 c	0.76 ab	8.50 b	3.54 c	0.89 ab
Selva	7.43 c	3.38 a	0.90 b	9.42 c	3,62 b	0.72 a	8.47 b	3.45 ab	1.05 c
Senga Sengana	6.43 b	3.50 b	0.85 ab	8.74 b	3.64 b	0.91 c	7.40 a	3.39 a	0.82 a

Explanation see Table 1.

Total soluble solids content, value of pH and titratable acidity varied depending on the strawberry cultivar and year of study (Table 5). Masny et al [19] obtained similar results.

Conclusions

1. Strawberry 'Elkat' and 'Kent' cultivars showed the highest marketable yield.
2. The high yield of unmarketable fruit was obtained for 'Elkat' and 'Senga Sengana'.
3. Gerida and 'Elsanta' produced the fruit of the greatest mass.
4. The highest content of L-ascorbic acid was noted for 'Elsanta' fruit.
5. 'Elkat' and 'Senga Sengana' fruit contained the most anthocyanins.
6. Total soluble solids, pH of juice and titratable acidity changed depending the year of study.

References

[1] Bojarska J.E., Czaplicki S., Zarecka K. and Zadernowski N.: Żywność. Nauka. Technologia. Jakość 2006, **2**(47) Suppl., 20–27.

[2] Cross J.V. and Burges C.M.: J. Hort. Sci. Biotechnol. 1998, **73**(5), 676–680.

[3] Daugaard H. and Lindhard H.: Gartenbauwissenschaft 2000, **65**, 213–217.
[4] Giusti M.M. and Wrolstad R.E.: [in:] Current Protocols in Food Analytical Chemistry. R.E. Wrolstad (Ed). John Wiley & Sons, NY 2001.
[5] Gwozdecki J.: Zesz. Nauk. Inst. Sadow. i Kwiac. 2000, **8**, 249–254.
[6] Kopytowski J., Kawecki Z., Bojarska J.E. and Stanys V.: Zesz. Nauk. Inst. Sadow. i Kwiac. 2006, **14**, 53–59.
[7] Laszlovszky-Zmarlicka A., Masny A., Cieśliński G. and Smolarz K.: Zesz. Nauk. Inst. Sadow. i Kwiac. 1997, **4**, 61–73.
[8] Małodobry M., Bieniasz M. and Doktor H.: Zesz. Nauk. A.R. Kraków, Sesja Nauk. 1999, **66**, 325–328.
[9] Małodobry M. and Bieniasz M.: Folia Hort. Ann. 2004, **16**(1), 79–85.
[10] Masny A., Laszlovszky-Zmarlicka A., Cieśliński G. and Smolarz K.: Zesz. Nauk. Inst. Sadow. i Kwiac. 1996, **3**, 37–47.
[11] Masny A., Markowski J. and Żurawicz E.: Zesz. Nauk. Inst. Sadow. i Kwiac. 2000, **8**, 255–261.
[12] Masny A., Markowski J. and Żurawicz E.: Folia Hort. Ann. 2001, **13**(1), 493–498.
[13] Masny A., Lewandowski M. and Żurawicz E.: [in:] Monografia „Zmienność genetyczna i jej wykorzystanie w hodowli roślin ogrodniczych". ISiK, Skierniewice 2005, p. 321–325.
[14] Vang-Petersen O.: Gartenbauwissenschaft 1998, **1**, 19–22.
[15] Skupień K.: Folia Hort. Supl. 2003, **1**, 221–223.
[16] Smolarz K. and Żurawicz E.: Prace ISiK, Skierniewice 1979, ser. A **23**, 83–95.
[17] Żmuda E., Wieniarska J. and Szember E.: Folia Univ. Agric. Stetin. 240, Agricultura 2004, **96**, 225–230.
[18] Żurawicz E. and Dominikowski J.: Zesz. Nauk. Inst. Sadow. i Kwiac. 1995, **2**, 5–11.
[19] Żurawicz E., Kruczyńska D. and Masny A.: Zesz. Nauk. Inst. Sadow. i Kwiac. 2005, **13**, 69–74.

STRUKTURA PLONU I ZAWARTOŚĆ NIEKTÓRYCH SKŁADNIKÓW W OWOCACH SZEŚCIU ODMIAN TRUSKAWKI

Katedra Sadownictwa i Pszczelnictwa, Wydział Ogrodniczy
Uniwersytet Rolniczy w Krakowie

Abstrakt: Badania prowadzono w latach 2002–2004 w Stacji Doświadczalnej Wydziału Ogrodniczego w Garlicy Murowanej koło Krakowa. Doświadczenie zostało założone w listopadzie 2000 r. Badaniami objęto sześć odmian truskawek: 'Elkat', 'Elsanta', 'Gerida', 'Kent', 'Selva' oraz 'Senga Sengana'.

Rośliny rozpoczęły owocowanie w 2002 r. W pierwszym roku plonowania uzyskano najwyższe plony owoców truskawek odmiany 'Elkat' oraz 'Kent'. W roku 2003 wszystkie odmiany cechowały się najmniejszym plonem w porównaniu z uzyskanymi z pozostałych dwóch lat badań. W trzecim roku owocowania największy plon owoców dały odmiany 'Kent' oraz 'Selva'. Dla odmian 'Elkat' oraz 'Senga Sengana' odnotowano najwyższy plon owoców niehandlowych zarówno w poszczególnych latach, jak i łącznie po trzech sezonach. Największe różnice w masie jednego owocu z pierwszych i ostatnich zbiorów stwierdzono w przypadku odmian 'Elkat', 'Gerida' oraz 'Kent' w latach 2002 i 2003. W przypadku odmian 'Gerida', 'Elsanta' oraz 'Kent' odnotowano największy procentowy owoców o średnicy 25 mm.

Słowa kluczowe: struktura plonu, witamina C, antocyjany

Vol. 18, No. 1 2011

Zenia MICHAŁOJĆ[1] and Halina BUCZKOWSKA[2]

YIELD AND EGGPLANT FRUIT QUALITY (*Solanum melongena* L.) DEPENDENT ON PLANT TRAINING AND NITROGEN FERTLIZATION

PLON I JAKOŚĆ OWOCÓW OBERŻYNY (*Solanum melongena* L.) W ZALEŻNOŚCI OD SPOSOBU PROWADZENIA ROŚLIN I NAWOŻENIA AZOTEM

Abstract: Studies upon the influence of varied forms and doses of nitrogen fertilizers as well as plant training on yields and eggplant fruit quality were carried out at The University of Life Sciences in Lublin in 2004–2005. Plants were trained in their natural form as well as for 3 carrying shoots. Following nitrogen nutrition forms were applied: ammonium (NH_4^+ – in a form of $(NH_4)_2SO_4$ 20.5 % N), nitrate (NO_3^- in a form of $Ca(NO_3)_2$ 13.5 % N), and amide (NH_2 in a form of $CO(NH_2)_2$ 46 % N), at following doses per 1 plant: 5, 10, 15 g N. Yields and number of fruits, as well as contents of dry matter, vitamin C and reducing sugars were determined.

It was found that the plant training method did not determine the size of eggplant fruit commercial yield, nor their number. Instead, it was observed that varied nitrogen rates significantly affected the yield size and fruit number. The highest yield was achieved when the highest nitrogen dose was applied (15 g N $\cdot$ plant^{-1} – 4.76 kg $\cdot$ m^{-2}), while the lowest yields were obtained after the lowest dose application (5 g N $\cdot$ plant^{-1} – 3.22 kg $\cdot$ m^{-2}). The average fruit number ranged to 17.7 fruits $\cdot$ m^{-2} and 11.7 fruits $\cdot$ m^2, respectively.

Achieved results referring to selected elements of fruit chemical composition indicated that the type of plant training did not influence on eggplant fruit quality. Varied nitrogen fertilization significantly affected the dry matter, ascorbic acid, and reducing sugars contents. Considering the yield size, fruit number, and reducing sugars contents, nitrate(V) form of nitrogen nutrition appeared to be the most favorable. Moreover, eggplant showed to have great requirements for nitrogen (15 g N $\cdot$ plant^{-1}).

Keywords: eggplant, training method, N form and dose, yield, vitamin C, sugars

Nice taste and great dietetic value of eggplant make that the vegetable finds more and more popularity in Poland and growing interests in its cultivation can be observed

[1] Department of Soil Cultivation and Fertilization of Horticultural Plants, University of Life Sciences in Lublin, ul. Leszczyńskiego 58, 20–068 Lublin, Poland, phone: +48 81 524 7126, email: zenia.michalojc@up.lublin.pl

[2] Department of Vegetable Crops and Medical Plants, University of Life Sciences in Lublin, ul. Leszczyńskiego 58, 20–068 Lublin, Poland, phone: +48 81 524 7116, email: halina.buczkowska@up.lublin.pl

[1–6]. Its large thermal requirements determine the commercial plantations of eggplant under covers [7–9].

Domestic studies upon the eggplant cultivation revealed that even 10 kg fruits · m^{-2} can be obtained from eggplant grown in a greenhouse [10–13], while up to 6 kg fruits · m^2 can be harvested from a plastic tunnel plantation [14–16]. The fertilization recommendations were worked out on a base of nutritional needs of tomato grown on an organic subsoil [17].

Taking into account growing interests in cultivating the eggplant in foil tunnels, it seems to be advisable to carry out studies upon its fertilization requirements in an aspect of yield quality [4–6, 18, 19].

Eggplant is a plant with great nutritional requirements, because it produces an enormous quantity of aboveground mass [20]. Therefore, many studies revealed that control of aboveground weight is necessary in eggplant cultivated under a cover. Cutting and training plants for 2–4 carrying shoots was assumed as optimum [8, 13, 21, 22].

The present study aimed at evaluating the influence of varied forms and doses of nitrogen nutrition on yields and quality of eggplant fruits that were cut and trained for 3 carrying shoots as well as in their natural form.

Material and methods

Study upon eggplant (*Solanum melongena* L.) of 'Epic' F_1 cv. was carried out in 2004–2005 in unheated plastic tunnel at The Experimental Farm of University of Life Sciences in Lublin in Felin. The eggplant seedling was prepared in a greenhouse according to rules recommended for that species. In both study years, seeds were sown at the beginning of March. Seedling was set into its place at the beginning of June. The vegetation period since seed sowing to the experiment completing lasted about 7 months (March 3 – September 13).

Plants were cultivated in foil cylinders of 10 dm^3 capacity each and at density of 3.3 plants per 1 m^2 (0.6 m × 0.5 m) on peat of initial pH 4.6, that was previously limed with $CaCO_3$ to pH = 6.5. The experiment was set in complete randomization design. Every combination was represented by 8 plants (experimental units).

The influence of three factors was examined:

1. Nitrogen forms:
   - NH_4^+ in a form of ammonium sulfate $(NH_4)_2SO_4$ (20.5 % N),
   - NO_3^- in a form of calcium nitrate $Ca(NO_3)_2$ (15.5 % N),
   - NH_2 in a form of urea $CO(NH_2)_2$ (46 % N),
2. Nitrogen doses: 5; 10; 15 g N · $plant^{-1}$,
3. Method of plant training: natural; 3 shoots.

Nitrogen, phosphorus, potassium, and magnesium fertilization for the whole vegetation period amounted to (per 1 plant):

- nitrogen (N) – 5; 10; 15 g N in form of $(NH_4)_2SO_4$; $Ca(NO_3)_2$; $CO(NH_2)_2$,
- phosphorus (P) – 7.0 g P in form of $Ca(H_2PO_4)_2 \cdot H_2O$ – 20.2 % P,
- potassium (K) – 16 g K in form of K_2SO_4 – 41.6 % K,
- magnesium (Mg) – 7.0 g Mg in form of ($MgSO_4 \cdot H_2O$ 17.4 % Mg).

Applied microelements were added as: EDTA–Fe, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, $MnSO_4 \cdot H_2O$, H_3BO_3 and $(NH_4)_2Mo_7O_{24} \cdot 4H_2O$ at amounts analogous to peat subsoils. All microelements, 1/2 phosphorus, as well as 1/7 nitrogen, potassium, and magnesium doses were applied during the subsoil preparation, before plant setting. Another phosphorus dose was introduced after the first fruit harvest, while remaining amounts of nitrogen, potassium, and magnesium were applied top dressing in 6 rates every 10 days. The subsoil water content was maintained at the level of 70 %.

Nursery operations and plant protection was performed in accordance to recommendations for the species. Fruits were harvested from every plant at their commercial maturity stage (mean fruit mass about 280 g), that was determined by intensive purple color with characteristic metallic shine. The harvest was made every 7 days in both study years: the first one – at the end of July, the last one – in the mid of September. Following yielding parameters were determined: commercial yield and number of commercial fruits per m^2.

Fruit samples were collected for chemical analyses in the mid of fruiting period at their commercial maturity stage. Following items were determined in fresh fruits: dry matter – by means of drier method, ascorbic acid content – according to Tillmans method, reducing sugars – according to Schoorl–Rogenbogen procedure.

Achieved results were statistically processed applying variance analysis. The difference significance was verified using multiple T-Tukey confidence intervals at significance level of $\alpha = 0.05$.

Results and discussion

Due to very close values of determined parameters, they are presented as average for both study years. In 2004–2005, mean commercial yield of eggplant fruits amounted to $3.96\ kg \cdot m^{-2}$ (Table 1).

Variance analysis did not reveal significant influence of three applied nitrogen forms on eggplant commercial yield. Regardless of nitrogen rate, mean commercial yield was as follows: ammonium sulfate – $4.09\ kg \cdot m^{-2}$, calcium nitrate – $3.75\ kg \cdot m^{-2}$, urea – $4.04\ kg \cdot m^{-2}$. Regardless of nitrogen form, statistically significant effect of nitrogen dose on fruit commercial yield was observed. Applied doses: 5; 10; 15 $g\ N \cdot plant^{-1}$ significantly differentiated the size of eggplant commercial yield. Considerably higher average eggplant fruits commercial yield was achieved when applying 15 $g\ N \cdot plant^{-1}$ ($4.76\ kg \cdot m^{-2}$), next in the case of 10 $g\ N \cdot plant^{-1}$ application ($3.90\ kg \cdot m^{-2}$), and the lowest one when nitrogen dose equaled 5 $g\ N \cdot plant^{-1}$ ($3.22\ kg \cdot m^{-2}$). When three nitrogen forms were used, the largest differentiation of fruit commercial yield was recorded between the lowest and the highest dose. Varied methods of plant training – natural form and for 3 shoots – did not have any significant influence on eggplant fruit commercial yield: $4.09\ kg \cdot m^{-2}$ and $3.84\ kg \cdot m^{-2}$ were achieved, respectively.

Studies performed in 2004 and 2005 revealed average commercial yield of eggplant fruits foil as $3.96\ kg \cdot m^{-2}$. Comparison of here achieved results with other authors' ones: $3.34\ kg \cdot m^{-2}$ [14], $4.39\ kg \cdot m^{-2}$ [15], $4.33\ kg \cdot m^{-2}$ [16] indicates that here presented values are similar to those obtained by those authors; although Markiewicz

Table 1

The effect of nitrogen fertilizer and training method on the marketable yield and number of marketable fruit of eggplant

Kind of N fertilizer	N dose [g · plant^{-1}]	Marketable yield [kg · m^{-2}]			Number of marketable fruit [No. · m^{-2}]		
		Training method			Training method		
		Natural form	3 shoots	Means	Natural form	3 shoots	Means
$(NH_4)_2SO_4$	5	3.42	3.44	3.43	11.7	12.5	12.1
	10	4.62	4.07	4.34	14.1	14.4	14.2
	15	4.47	4.53	4.50	17.5	16.7	17.1
Mean for $(NH_4)_2SO_4$		4.17	4.01	4.09	14.4	14.5	14.4
$Ca(NO_3)_2$	5	3.07	2.72	2.90	10.6	9.2	9.9
	10	3.85	3.10	3.47	13.9	12.5	13.2
	15	4.82	4.96	4.89	18.1	17.1	17.6
Mean for $Ca(NO_3)_2$		3.91	3.59	3.75	14.2	12.9	13.6
$CO(NH_2)_2$	5	3.31	3.39	3.35	12.3	14.0	13.2
	10	3.95	3.81	3.88	13.7	16.2	15.0
	15	5.28	4.52	4.90	20.6	16.0	18.3
Mean for $CO(NH_2)_2$		4.18	3.91	4.04	15.5	15.4	15.5
Mean for dose N	5	3.27	3.18	3.22	11.5	11.9	11.7
	10	4.14	3.66	3.90	13.9	14.4	14.2
	15	4.86	4.67	4.76	18.7	16.6	17.6
Total mean		4.09	3.84	3.96	14.7	14.3	14.5
$LSD_{0.05}$	Kind N (a)			n.s.*			n.s.
	Dose N (b)			0.450			1.93
	Trainig method (c)			n.s.			n.s.
	Interaction: a b			1.032			4.19
	b c			0.773			3.14
	a c			n.s.			n.s.
	a b c			1.638			6.66

* n.s. – not significant.

and Golcz [4] recorded higher yields from plantation in a plastic tunnel – 8.37 kg · m^{-2}. Different nitrogen forms had not significant influence on yield size of eggplant fruits harvested from peat subsoil. Instead, significant dependence of yield on nitrogen rate was reported. Applying the largest nitrogen dose (15 g N · plant^{-1}) caused the increase of commercial yield by 48 % as compared with that achieved when the lowest nitrogen rate was applied (5 g N · plant^{-1}). Markiewicz and Golcz [4] in their study upon different levels of nutrients during eggplant cultivation on peat subsoil, recorded the largest yield increase (22 %) at the highest fertilization level.

Considering the results of fruit number, no significant effect of varied nitrogen forms on examined parameter were observed. Regardless of nitrogen dose, number of commercial eggplant fruits from plant fertilized with ammonium sulfate amounted to 14.4 m^{-2}, while when calcium nitrate and urea were applied equaled 13.6 fruits $\cdot$ m^{-2} and 15.5 fruits $\cdot$ m^{-2}, respectively. Regardless of nitrogen form, significant influence of nitrogen dose on that yielding parameter was found. Significantly larger number of commercial eggplant fruits (17.6 fruits $\cdot$ m^{-2}) was achieved due to application of 15 g N $\cdot$ $plant^{-1}$ as comparing with 10 g N $\cdot$ $plant^{-1}$ (14.2 fruits $\cdot$ m^{-2}), as well as to 5 g N $\cdot$ $plant^{-1}$ rate which resulted in significantly less number of fruits (11.7 fruits $\cdot$ m^{-2}). It was found that when nitrogen in its three forms was applied, the largest differentiation, referring to the fruit number, was recorded between its lowest and the highest dose. The type of eggplant training did not exert any considerable effect on examined parameter. From plants trained in their natural form as well as for 3 carrying shoots, 14.7 fruits $\cdot$ m^{-2} and 13.3 fruits $\cdot$ m^{-2}, respectively, were achieved.

Biological value was assesses on a base of dry matter, ascorbic acid, and reducing sugars contents at fresh eggplant fruits of 'Epic' F_1 cv. Results are presented in Table 2.

Dry matter content ranged from 6.77 % to 8.03 %, at mean value 7.42 %. A significant influence of varied nitrogen forms and doses on dry matter content was found, but no effect of plant training method was recorded. Significantly higher average value (7.7 1%) was reported for eggplant fruits from plants fertilized with NO_3^- form (calcium nitrate) as compared with other nitrogen forms. Furthermore, considerably higher dry matter content was found at fruits as a result of fertilization with nitrogen at 10 and 15 g N $\cdot$ $plant^{-1}$ rates as comparing with the lowest dose (Table 2). Studies made by Herrmann [1] and Kowalski et al [3] upon chemical composition of eggplant revealed similar content of dry matter in fruits.

Content of ascorbic acid at eggplant fruits amounted from 6.13 to 8.49 mg $\cdot$ 100 g^{-1} f.m. Among three examined factors, only nitrogen dose had significant influence on it (Table 2). Considerably lower content of ascorbic acid was found when the highest nitrogen rate was applied (15 g N) as compared with other ones. There is no information in available literature references on the effect of nitrogen doses on vitamin C content in eggplant fruits. Study performed by Kowalski et al [3] presented the evaluation of ascorbic acid content in fruits of several eggplant cultivars and it was concluded that it oscillated around 20 mg $\cdot$ 100 g^{-1} f.m. at 'Epic' F_1 cv., which was higher than that recorded by other authors: 5.54 mg $\cdot$ 100 g^{-1} f.m. [10] and 5.89 mg $\cdot$ 100 g^{-1} f.m. [14].

Considering the carbohydrates separated from a fresh matter of eggplant fruits, mean content of reducing sugars was determined (2.50 %). Similar sugars level at eggplant fruits was found by Herrmann [1], Cebula [10], as well as Ambroszczyk and Cebula [13, 23] at eggplant grown in a greenhouse, while Gajewski and Gajc-Wolska [14] found twice as much reducing sugars. The variance analysis revealed significant influence of applied nitrogen forms on reducing sugars contents: their highest level (2.60 %) was found at fruits of plants fertilized with urea (NH_2), whereas the lowest (2.31 %) at those treated with ammonium sulfate (NH_4^+). No effects of nitrogen dose on

Table 2

The content of dry matter vitamin C and reduced sugars in eggplant fruits depending on nitrogen fertilizer and training method

Kind of N fertilizer	N dose [g · plant^{-1}]	Dry matter [%]			Vitamin C [mg · 100 g^{-1} f.m.]			Reduced sugars [g · 100 g^{-1} f.m.]		
		Training method			Training method			Training method		
		Natural form	3 shoots	Mean	Natural form	3 shoots	Mean	Natural form	3 shoots	Mean
$(NH_4)_2SO_4$	5	6.77	7.20	6.99	8.49	7.10	7.79	2.15	2.42	2.29
	10	7.60	7.02	7.31	8.08	7.32	7.70	2.18	2.23	2.21
	15	7.35	7.44	7.40	6.98	6.91	6.95	2.37	2.50	2.43
Mean for $(NH_4)_2SO_4$		7.24	7.22	7.23	7.85	7.11	7.48	2.23	2.38	2.31
$Ca(NO_3)_2$	5	7.49	7.57	7.53	7.92	7.91	7.92	2.48	2.53	2.50
	10	7.72	7.93	7.83	8.21	7.83	8.02	2.55	2.56	2.56
	15	7.53	8.03	7.78	6.70	7.32	7.01	2.59	2.76	2.68
Mean for $Ca(NO_3)_2$		7.58	7.84	7.71	7.61	7.69	7.65	2.54	2.62	2.58
$CO(NH_2)_2$	5	7.27	7.22	7.25	7.19	7.92	7.55	2.51	2.63	2.57
	10	7.36	7.19	7.27	6.72	7.32	7.02	2.40	2.77	2.58
	15	7.85	7.09	7.47	6.13	7.31	6.72	2.73	2.59	2.66
Mean for $CO(NH_2)_2$		7.49	7.17	7.33	6.68	7.52	7.10	2.54	2.66	2.60

Table 2 contd.

Kind of N fertilizer	N dose [g · plant^{-1}]	Dry matter [%]			Vitamin C [mg · 100 g^{-1} f.m.]			Reduced sugars [g · 100 g^{-1} f.m.]		
		Training method			Training method			Training method		
		Natural form	3 shoots	Mean	Natural form	3 shoots	Mean	Natural form	3 shoots	Mean
Mean for dose N	5	7.18	7.33	7.25	7.87	7.64	7.75	2.38	2.53	2.45
	10	7.56	7.38	7.47	7.67	7.49	7.58	2.38	2.52	2.45
	15	7.58	7.52	7.55	6.60	7.18	6.89	2.56	2.62	2.59
Total mean		7.44	7.41	7.42	7.38	7.44	7.41	2.44	2.56	2.50
$LSD_{0.05}$	Kind N (a)			0.222			n.s.			0.103
	Dose N (b)			0.222			0.733			0.103
	Trainig method (c)			n.s.			n.s.			0.070
	Interaction:	a b		0.515			n.s.			0.239
		b c		0.384			n.s.			0.178
		a c		0.384			n.s.			0.178
		a b c		0.824			n.s.			0.382

reducing sugars contents at eggplant fruits were observed (Table 2). Instead, the effect of plant training method on reducing sugars content appeared to be significant. More sugars were found in fruits of plants that trained for three shoots rather than in natural form. This dependence can be explained by better light access, which determines the carbohydrate synthesis. It was earlier stated by studies made by Cebula [24], Ambroszczyk and Cebula [13] and Ambroszczyk et al [22].

Conclusions

1. The method of plant training did not determine the commercial yield and fruit number, nor dry matter and ascorbic acid contents at eggplant fruits; instead, it differentiated the reducing sugars content.

2. Applied nitrogen forms significantly affected the dry matter and reducing sugars contents at eggplant fruits, while they had no effect on yield and ascorbic acid level.

3. Applied nitrogen doses considerably affected the yield size, fruit number, and fruit quality.

4. At eggplant cultivated on peat subsoil, dose of 15 g N $\cdot$ plant^{-1} in a form of calcium nitrate should be considered as optimum nitrogen nutrition.

References

[1] Herrmann K.: Ind. Obst- Gemüseverwert. 1996, **9**, 285–288.
[2] Russo V.M.: J. Sci. Agric. 1996, **71**, 119–123.
[3] Kowalski R., Kowalska G. and Wierciński J.: Folia Hort. 2003, **15**(2), 89–95.
[4] Markiewicz B. and Golcz A.: Biul. Nauk. 2003, **22**, 249–252.
[5] Michałojć Z. and Buczkowska H.: J. Elementol. 2008, **13**(2), 269–275.
[6] Michałojć Z. and Buczkowska H.: J. Elementol. 2009, **14**(1), 111–119.
[7] Passam H.C. and Khah E.M.: Sci. Hort. 1992, **51**, 179–185.
[8] Paksoy M. and Akilli M.: Acta Hort. 1994, **366**, 287–290.
[9] Romano D. and Leonardi C.: Acta Hort. 1994, **53**, 382–341.
[10] Cebula S.: Acta Agrar. Silv., Ser. Agr. 1996, **34**, 1–11.
[11] Cebula S.: Folia Hort. 2003, **15**(2), 71–76.
[12] Cebula S. and Ambroszczyk A.M.: Acta Agr. Silv., Ser. Agr. 1999, **37**, 49–57.
[13] Ambroszczyk A.M. and Cebula S.: Acta Agr. Silv., Ser. Agr. 2002–2003, **XLI**, 71–81.
[14] Gajewski M. and Gajc-Wolska J.: Zesz. Nauk. ART, Bydgoszcz 1998, **215**, 69–72.
[15] Kowalska G.: Folia Hort. 2003, **15**(2), 77–87.
[16] Buczkowska H.: Zesz. Nauk. AR, Wrocław, Rolnictwo 2005, **515**, 61–67.
[17] Uliński Z. and Glapś T.: Nowości Warzyw. 1988, **19**, 103–110.
[18] Golcz A., Potylicka B. and Markiewicz B: Roczn. AR, Pozn., CCCLXX, Ogrodnictwo 2005, **39**, 13–19.
[19] Markiewicz B., Golcz A. and Potylicka B.: Roczn. AR, Pozn., CCCLVI, Ogrodnictwo 2004, **37**, 153–157.
[20] Kaufmann H.G. and Vorwerk R.: Arch. Gartenbau. 1971, **19**(1), 7–27.
[21] Pessarakli M.M. and Dres R.: Food Agr. Environ. 2003, **1**(2), 215–216.
[22] Ambroszczyk A.M., Cebula S. and Sękara A.: Veg. Crops Res. Bull. 2008, **68**, 57–70.
[23] Ambroszczyk A.M. and Cebula S.: Roczn. AR, Poznań, CCCXXIII, Ogrodnictwo 2000, **31**(2), 209–213.
[24] Cebula S.: Zesz. Nauk. ART, Bydgoszcz 2001, **234**, 39–44.

PLON I JAKOŚĆ OWOCÓW OBERŻYNY (*Solanum molongena* L.) W ZALEŻNOŚCI OD SPOSOBU PROWADZENIA ROŚLIN I NAWOŻENIA AZOTEM

[1] Katedra Uprawy i Nawożenia Roślin Ogrodniczych
[2] Katedra Warzywnictwa i Roślin Leczniczych
Uniwersytet Przyrodniczy w Lublinie

Abstrakt: Badania nad wpływem zróżnicowanych form i dawek azotu oraz sposobu prowadzenia roślin na plon i jakość owoców oberżyny przeprowadzono w latach 2004–2005 w Uniwersytecie Przyrodniczym w Lublinie. Rośliny prowadzono w formie naturalnej oraz na 3 pędy przewodnie. Zastosowano zróżnicowane formy azotu: amonową (NH_4^+ – w postaci $(NH_4)_2SO_4$ 20,5 % N), saletrzaną (NO_3^- w postaci $Ca(NO_3)_2$ 13,5 % N) oraz amidową (NH_2 w postaci $CO(NH_2)_2$ 46 % N), stosując na 1 roślinę: 5, 10, 15 g N. Oceniono plon oraz liczbę owoców, a także zawartość w nich suchej masy, witaminy C i cukrów redukujących. Wykazano, że sposób prowadzenia roślin nie decydował o wielkości plonu handlowego owoców, a także o ich liczbie. Stwierdzono natomiast, że różnicowane dawki azotu istotnie oddziaływały na wielkość plonu i liczbę owoców. Największy plon uzyskano po zastosowaniu największej dawki azotu (15 g N · roślinę$^{-1}$ – średnio 4,76 kg · m^{-2}), a najmniejsze po zastosowaniu najmniejszej jego dawki (5 g N · roślinę$^{-1}$ – średnio 3,22 kg · m^{-2}). Liczba owoców wynosiła średnio odpowiednio 17,7 szt. · m^{-2} oraz 11,7 szt. · m^{2}.

Uzyskane wyniki dotyczące wybranych elementów składu chemicznego owoców wskazują, że sposób prowadzenia roślin nie miał wpływu na jakość owoców oberżyny. Natomiast zróżnicowane nawożenie azotem istotnie oddziaływało na zawartość suchej masy, witaminy C i cukrów redukujących. Mając na uwadze wielkość plonu, liczbę owoców oraz zawartość cukrów redukujących należy podkreślić korzystne oddziaływanie saletrzanej formy azotu oraz duże wymagania oberżyny w stosunku do tego pierwiastka (15 g N · roślinę$^{-1}$).

Słowa kluczowe: oberżyna, metody prowadzenia, formy azotu, dawki azotu, plon, witamina C, cukry

Vol. 18, No. 1 2011

Maria POBOŻNIAK[1] and Adam ŚWIDERSKI[2]

INITIAL RESEARCH ON THE INFLUENCE OF THE COLOUR OF THE PEA LEAVES ON THE INFESTATION BY THRIPS

WSTĘPNE BADANIA NAD WPŁYWEM BARWY LIŚCI GROCHU NA ZASIEDLENIE PRZEZ WCIORNASTKI

Abstract: Based on the spectrophotometer analysis and the statistical data processing it was found that the colour of the pea leaves significantly influences the infestation by thrips. The positive correlation was found between summary content of chlorophylls in the pea leaves, represented by the absorbance at $\lambda = 680$ nm and the average number of thrips. The greater content of the chlorophylls was noticed for the cultivars heavier infested by thrips ('Hazard', 'Walor', 'Jubilat' and 'Maraton') and the lower concentration of chlorophylls was found for the cultivars less infested by thrips.

Keywords: thrips, peas, chlorophylls level, leaf colour

The thrips (*Thysanoptera*) have negative influence on the cultivation of the pea. They feed on leaves, flower buds, flowers and pods causing atrophy, deformation and preventing nucleation. The pea plantations are threatened by the infestation of thrips during the whole vegetation period [1, 2].

Due to the tendencies to limit the use of pesticides, especially in the plantation intended for consumption, it is of vital importance to find and cultivate the pea cultivars resistant to or tolerating the feeding pests. The research of many authors suggests that the visual stimulus is the initial factors influencing the selection of plants by insects and that the plant tissue can also effect the infestation by thrips [3, 4]. This is related to the ability of insects for the reception of the light waves reflected from the surface of the leaves or coming through the leaves of wide range of wavelengths (from $\lambda = 260$ nm – ultraviolet to $\lambda = 720$ nm – red) [5]. Because of this, the antixenotic resistance of plants can vary depending on the differences in colour of the different fragments of

[1] Department of Plant Protection, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 5258, email: mpobozniak@ogr.ar.krakow.pl

[2] Department of Biochemistry, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 51 95, email: a.swiderski@agr.ur.krakow.pl

plants, for example of leaves. Such differences were found, among other, in the resistance of the cabbage on *Pieris* sp., spinach and red garden beet on *Aphis fabae* [6–8]. Very few studies have been carried out with plants in order to identify the patterns of resistance against thrips. Up to now, the only trial on antixenotic resistance against onion thrips under field conditions as well as laboratory was carried out by Fail et al [9] and Stoner and Shelton [10]. The number of works about the influence of the colour on the behaviour of thrips during the plant selection and infestation is also very limited [11, 12].

Material and methods

In the research carried out at the Experimental Station in Mydlniki in 2008, 16 cultivars of eatable pea differencing in the purpose and the length of the maturation were used. These cultivars are listed in Table 1. All pea cultivars were sown on 31st March, on plots of 4 m × 16 m. To demonstrate the relations between the intensity of the green colour of the leaves in particular pea cultivars and the degree of infestation by thrips, the analysis of colour of leaves using analysis of leaf colour was performed on the basis of visible light absorption spectra of tissue samples obtained with a JASCO V-530 spectrophotometer. This allowed *in vivo* colour characteristics to be made on fresh leaves, on the basis of chlorophylls and carotenoids they contain [data not published]. The fragments of leaves were collected on 15th May. The degree of infestation of particular pea cultivars by thrips was estimated on the plants using the standard entomological sweep net. To collect one sample, 25 capturing movement with sweep net were made. Four samples were collected from each species. The samples were collected two times during the phase of main pea sprout forming. The obtained results were statistically analysed using Statistica 6.0.

Results and discussion

The degree of infestation of particular pea cultivars by thrips was varying. The total mean number of thrips collected on 16 pea cultivars during the period of main pea sprout forming was from 32 to 3.2 thrips per1 sample. The significantly higher number of thrips was collected on ‘Hazard’ cv., and then on ‘Walor’, ‘Pionier’, ‘Demon’, ‘Jubilat’ and ‘Maraton’ cultivars, while the lowest number was noticed on ‘Polar’, ‘Duet’ and ‘Cud Kelwedonu’ cultivars. The analysis of the mean number of thrips collected during individual analysis and the mean total number show significant differences between tested cultivars. The results from the first collection of thrips show significant statistical differences between the most infested cultivars ‘Hazard’ and ‘Pionier’ and the low infested cultivars ‘Polar’, ‘Baron’, ‘Cud Kelwedonu’ and ‘Muskat’. The comparison of mean numbers of thrips gathered in the second collection and the summary average indicate the significant differences between cultivars ‘Hazard’ and ‘Walor’, and the cultivars ‘Polar’ and ‘Duet’ (Table 1).

Table 1

Mean number of thrips collected from peas with sweep net

Cultivar	Analysis		Mean
	1st analysis	2nd analysis	
Baron F_1	1.3 a	7.7 ab	4.5 ab
Bohun F_1	4.0 abc	6.3 ab	5.2 ab
Cud Kelwedonu F_1	1.3 a	5.3 ab	3.3 ab
Demon F_1	4.7 abc	16.7 cd	10.7 ab
Domino F_1	3.2 abc	8.0 ab	6.2 ab
Duet F_1	3.0 abc	4.0 a	3.5 a
Hazard F_1	44.0 e	20.7 d	32.0 d
Hetman F_1	3.7 abc	6.3 ab	5.0 ab
Jubilat F_1	10.0 cd	10 ab	10.0 bc
Kaskada F_1	2.3 ab	5.7 ab	4.0 ab
Maraton F_1	5.7 abc	11.7 ab	8.7 ab
Muskat F_1	1.7 a	12.3 bc	7.0 ab
Pionier F_1	15.7 d	8.0 ab	11.8 abcd
Polar F_1	1.0 a	5.0 a	3.2 a
Set F_1	4.0 abc	6.3 ab	5.2 ab
WalorF_1	9.3 abc	20.3 d	14.8 c

Means in the columns marked with different letters are significantly different at $p \leq 0.05$.

Table 2

Absorption at $\lambda = 680$ nm reflecting the contents of chlorophylls read from absorption spectrum of pea leaves

Cultivar	Repetitions				A_{mean}	Relative error [%]
	A_1	A_2	A_3	A_4		
Baron F_1	0.73	1.20	1.20	1.00	1.03	21.6
Bohun F_1	1.00	1.04	1.25	1.40	1.17	16.0
Cud Kelwedon F_1	1.29	1.30	1.30	1.34	1.31	1.7
Demon F_1	1.42	1.54	1.60	1.25	1.45	10.6
Domino F_1	1.28	1.14	1.40	1.52	1.34	12.2
Duet F_1	1.10	1.10	1.37	1.23	1.20	10.7
Hazard F_1	1.31	1.40	1.43	1.42	1.39	3.9
Hetman F_1	1.30	1.30	1.38	1.40	1.35	3.9
Jubilat F_1	1.57	1.60	1.48	1.55	1.55	3.3
Kaskada F_1	1.40	1.00	1.58	1.23	1.30	19.0
Maraton F_1	1.40	1.37	1.36	1.25	1.35	4.9
Muskat F_1	1.26	1.55	1.36	1.42	1.40	8.7
Pionier F_1	1.30	1.28	1.30	1.16	1.26	5.3
Polar F_1	1.00	1.22	1.38	1.30	1.23	13.4
Set F_1	1.47	1.57	1.50	1.60	1.54	3.9
Walor F_1	1.90	1.72	1.60	1.51	1.68	10.0

To find one of the possible reasons for the different degree of infestation, the colours of leaves were compared. It was found in most cases, that the cultivars heavier infested by thrips have greater content of chlorophylls, while the cultivars less infested have the lower content of chlorophylls (Tables 1 and 2).

The examples of absorption spectrum of pea leaves for 'Polar' and 'Walor' cultivars are given in Fig. 1.

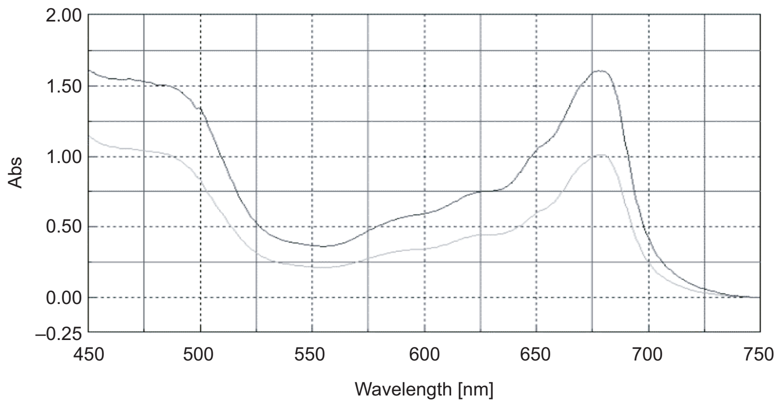

Fig. 1. The examples of absorption spectrums of pea leaf samples in the range of visible light from 450 to 750 nm; The blue line (higher) – 'Walor' cv., the green line (lower) – 'Pionier' cv.; The greater absorption at λ_{max} = 680 nm represents higher content of chlorophylls

The band in the spectrum with maximum at λ_{max} = 880 nm is only due to the presence of chlorophylls, and the rest of spectrum is also due to the presence of carotenoids in leaves. The higher absorption within this range represents the darker green due the greater content of chlorophylls or thickness of leaves. For 'Walor' cultivar, which was more infested, the greater absorption was noticed within nearly whole range of visible light, however the most significant difference was noticed for λ = 680 nm.

The positive Spaerman correlation between summary content of chlorophylls in the pea leaves, represented by the absorbance at λ = 680 nm, and the average number of thrips collected on the plants and the summary average was found (Table 3). At the same time, no better correlations between other wavelengths were found, especially at the wavelength of λ = 470 nm, which should show the potential influence of the carotenoids on the background of chlorophylls. Also no anthocyanin pigments were found on the pea leaves, which is in line with the other results presented in the literature. These results confirm and suggest that the different intensity of the green colour of leaves can be treated as one of the factors deciding about the attractiveness of pea plants for thrips.

The research on the antixenotic resistance of different cabbage cultivars against infestation by *Thrips tabaci* Fail et al [9] shows that the groups of resistant cultivars have greater reflectance intensity than the group of susceptible.

Table 3

Correlation of R Spaermana between absorption at λ = 680 nm reflecting the contents of chlorophylls read from absorption spectrum on pea leaves and the infestation by thrips

The examined parameters of infestation	$R_{Spearmana}$
Absorbance at 680 nm – mean number of thrips for 1st analysis	0.258006
Absorbance at 680 nm – mean number of collected thrips for 2nd analysis	0.603938
Absorbance at 680 nm – total mean number of thrips	0.417145

The selected correlations are significant at $p < 0.001$.

The influence of the intensity of green colour of leaves is also confirmed by the works of other authors. According to Myers [6] the female of *Pieris* sp. preferred the cabbage cultivars having more intensive green colour of leaves. The research by Luczak [13] indicates that the winged forms of black bean aphids preferred the cultivars of sugar beet with light-green leaves, having the lower contents of vegetable dyes, especially yellow and orange (flavones and carotenoids). The similar results were received in the case of spinach and the garden beet [7, 8]. Such relationships were also observed in the infestation of cauliflower by *Brevocoryne brassicae* [14].

Conclusions

Based on the spectrophotometric analysis and the statistical data processing it was found that the colour of the pea leaves significantly influences the infestation by thrips. The intensity of absorbance demonstrated by pea leaves in the range of red light with a maximum at λ = 680 nm has the positive effect on the infestation of pea by thrips. The most important factor deciding about the attractiveness was the intensity of the green color, which is the typical feature of the pea, and less significant were the minor differences in the leaf colors caused by the different contents of the carotenoids, chlorophyll *a* and chlorophyll *b*.

Acknowlegement

This research was supported by the Polish State Committee for Scientific Research grant No. N N310 142135.

References

[1] Wnuk A. and Pobożniak M.: J. Plant Protect. Res. 2003, **43**(2), 77–85.
[2] Zawirska I.: Prace Nauk. IOR 1969, **11**(2), 41–79.
[3] Harborne J.B.: Ekologia biochemiczna. PWN, Warszawa 1997.
[4] Leszczyński B., Warchoł J. and Niraz S.: Ochr. Rośl. 1985, **5**, 5–6.
[5] Boczek J.: Post. Nauk Roln. 1977, **5**, 71–84.
[6] Myers J.H.: Anim. Ecol. 1985, **54**(1), 198–204.
[7] Łuczak I. and Gawęda M: Folia Hort. 1991, **III**(3), 27–37.
[8] Łuczak I.: Zesz. Nauk. AR w Krakowie, 287, Ogrodnictwo 1993, **21**, 115–127.
[9] Fail J., Zana J. and Penzes B.: Acta Phytophatol. Entomol. Hung. 2008, **43**(2), 267–275.

[10] Stoner K.A. and Shellton A.: J. Econ. Entomol. 1988, **81**, 1190–1195.
[11] Kirk W.D.J.: J. Chem. Ecol. 1985, **11**, 35–43.
[12] Morse J.G. and Hoddle M.S.: Ann. Rev. Entomol. 2005, **51**, 67–89.
[13] Łuczak I.: Zesz. Nauk. AR w Krakowie 1998, **234**, pp. 146.
[14] Singh R. and Ellis P.R.: IOBC/WPRS Bull. 1993, **16**(5), 21–35.

WSTĘPNE BADANIA NAD WPŁYWEM BARWY LIŚCI GROCHU NA ZASIEDLENIE PRZEZ WCIORNASTKI

[1] Katedra Ochrony Roślin
[2] Katedra Biochemii
Uniwersytet Rolniczy w Krakowie

Streszczenie: W wyniku przeprowadzonych analiz spektrofotometrycznych i opracowania statystycznego stwierdzono, że barwa liści grochu ma istotny wpływ na zasiedlenie ich przez wciornastki. Dla badanych odmian stwierdzono pozytywną korelację pomiędzy sumaryczną zawartością chlorofili w liściach grochu, oznaczoną poprzez pomiar absorbancji przy λ = 680 nm, a średnią liczebnością wciornastków. Odmiany silniej zasiedlane przez wciornastki ('Hazard', 'Walor', 'Jubilat' i 'Maraton') odznaczały się większą zawartością chlorofili, z kolei mniej licznie zasiedlane odmiany ('Polar' i 'Duet') należały do grupy odmian o mniejszej zawartości chlorofili.

Słowa kluczowe: wciornastki, groch, poziom chlorofili, barwa liści

Vol. 18, No. 1 2011

Marek SIWULSKI[1], Agnieszka JASIŃSKA[1],
Krzysztof SOBIERALSKI[1] and Iwona SAS-GOLAK[1]

COMPARISON OF CHEMICAL COMPOSITION OF FRUITING BODIES OF SOME EDIBLE MUSHROOMS CULTIVATED ON SAWDUST

PORÓWNANIE SKŁADU CHEMICZNEGO OWOCNIKÓW WYBRANYCH GRZYBÓW UPRAWIANYCH NA PODŁOŻU Z TROCIN

Abstract: In the present research the chemical compositions of fruiting bodies of two strains of *Lentinula edodes*, two strains of *Pleurotus eryngii*, *Auricularia auricula-judae* and *A. polytricha* were assessed. Above-mentioned mushrooms were cultivated on birch and beech sawdust. The content of protein, fat, carbohydrates and ash in fruiting bodies was assessed.

The results obtained show that the cultivation substrate influenced the chemical compositions of fruiting bodies of examined mushroom species and strains. The highest amount of protein was found in fruiting bodies of *P. eryngii;* but fruiting bodies of *L. edodes* contained the highest amount of fat and ash. Fruiting bodies of the genus *Auricularia* was characterized by the highest content of carbohydrates.

Keywords: *Lentinula edodes*, *Pleurotus eryngii*, *Auricularia auricula-judae*, *Auricularia polytricha*, fruiting bodies, chemical composition, sawdust

Pleurotus eryngii and *Lentinula edodes* are commonly cultivated edible mushrooms all over the world and gather more attention within Polish mushroom growers. Although both, *Auricularia auricula-judae* and *Auricularia polytricha* are species less known on the Polish market, similar way of cultivation as *Lentinula edodes*, together with their tasty fruiting bodies and spectacular medical properties are highly recommended for commercial cultivation [1]. Mushrooms are rich in protein, minerals and vitamins [2]. For the reason that part of the harvested fruiting bodies is designated for processing main emphasis is placed on their chemical composition. Many authors show significant differences in chemical composition among different species and strains of cultivated mushrooms [3–6]. The latest reports show growing interest in the new edible mushrooms available for commercial cultivation in Europe [7].

[1] Department of Vegetable Crops, Poznan University of Life Sciences, ul. Dąbrowskiego 159, 60–594 Poznań, Poland, phone: +48 61 848 7974, email: fungus@up.poznan.pl

The aim of this study was to evaluate the chemical composition ie water, protein, fat, carbohydrates and ash values, of fruiting bodies of different edible mushrooms cultivated on two sawdust substrates.

Materials and methods

The investigation was carried out at the Department of Vegetable Crops of Poznan University of Life Sciences in 2008. The subjects of the study were four species of edible mushrooms cultivated on two sawdust substrates.

Investigated species and strains were as follows:

– *Lentinula edodes* 'SH 37' and 'SH 27',
– *Pleurotus eryngii* 'B124' and 'B127,'
– *Auricularia auricula-judae*,
– *Auricularia polytricha*.

Sawdust of beech and birch were used as a growing substrate, supplemented with 20 % (w/w) of wheat bran and 0.2 % $CaCO_3$. After mixing the components, the substrates were watered up with tap water to the moisture content of 65 %.

In the experiment substrates were packed into PP foil bags with filter (0.02 μm). Each bag contained 2.5 kg of substrate. Bags with the substrates were sterilized at 121 ^{o}C for 2 h. After cooling to the room temperature (ca 21 ^{o}C) the substrates were inoculated with the spawn of tested mushroom strains in the amount equal to 3 % of substrates dry weight. Next, substrates were incubated at 25 ^{o}C and 80–90 % RH until all the substrates volume was grown through by the mycelium. After incubation bags were transferred into cultivation room with temperature of 13–15 ^{o}C, for *A. auricula--judae* and *A. polytricha* the temperature was increased up to 22 ^{o}C after appearance of primordial. The humidity in case of all mushrooms was similar and valued from 85 to 90 %. Cultures were lighted with fluorescent light (Day-Light) of 500 lx intensity for 12 h a day. Fruiting bodies were set on the upper surface of the substrate. The cultivation was conducted in two cycles.

After harvesting the fruiting bodies were dried in 50 ^{o}C for 8 hours and then dried at 80 ^{o}C to constant weight and ground to powder.

Contents of water, protein, fat, carbohydrates and ash were determined using analytical methods described by Rutkowska [8].

Data obtained were evaluated by analysis of variance (ANOVA) and Tukey's mean homogeneity test were used to indicate the significant differences between the means values ($p < 0.01$). Each value was the average of three replicates from both cycles of cultivation.

Results and discussion

According to various authors, nutrient values of the mushrooms differ between the species. Chang and Miles [9] note that moisture of fruiting bodies can rate from 73 to 91 % of fresh mass and carbohydrates from 57 to 82 % of dry mass. Protein content in mushroom normally ranges between 20 and 40 % and it is digested easier than the protein from many legume sources like soybeans and peanuts. The mushrooms fruiting bodies are low in fat which makes them good component of dietary products (3.7–10.0 %) [10, 11].

In presented study, different cultivation substrates influenced the chemical composition of evaluated mushrooms. However, moisture content did not vary among studied dried mushrooms and was similar in all investigated fruiting bodies, regardless the cultivation substrate.

Two different substrates used for cultivation influenced especially the content of protein and carbohydrates in all investigated mushrooms.

Fruiting bodies of all investigated mushrooms contained higher amount of protein when cultivated on beech sawdust compared with birch sawdust (Table 1). The 'SH37' strain of *L. edodes* contained higher amount of protein than 'SH27'one regardless the substrate. Furthermore, in *P. eryngii* 'B127' and 'B124' the protein content was higher in fruiting bodies obtained from cultivation on beech sawdust (18.35 % and 17.87 %, respectively). In *A. auricula-judae* the highest amount of protein was found in fruiting bodies grown on beech sawdust (10.24 %). Furthermore, surprisingly on the same substrate *A. polytricha* showed the lowest its amount (6.30 %). This can be explained by individual character of the species. *A. auricula-judae* cultivated on birch sawdust contained second highest amount of protein (8.99 %).

Amount of carbohydrates in fruiting bodies in both strains of *L. edodes* was higher when cultivated on birch sawdust compared with beech sawdust (68.54 and 68.41 %, respectively), as well as in *P. eryngii* 'B127', simultaneously this amount was the highest amount among the strains (62.03 %). Regarding genus *Auricularia*, content of carbohydrates was higher in mushrooms grown on birch sawdust, and was higher in carpophores of *A. polytricha* (83.30 %) than in *A. auricula-judae* (82.11 %) but those means did not vary statistically.

Generally, fruiting bodies of the genus *Auricularia* showed the biggest variation among the evaluated species and cultivation substrates (Table 1). The biggest differences between the means were observed in protein content in fruiting bodies.

In presented study, examined mushroom species and strains contained different amounts of protein, fat, carbohydrates and ash in the fruiting bodies (Fig. 1).

Fruiting bodies of both strains of *P. eryngii* ('B124' and 'B127') contained the highest amount of protein (17.04 and 17.16 %, respectively). Those means were lower than reported by Breene [12] and Cheung [13] – 19.8 %, however higher than in the experiment of Dundar et al [14] – 11.95 %. Use of different cultivation substrates within mentioned experiments could be explanation of this fact. Dundar et al [14] grew *P. eryngii* on wheat stalk, which is much easier to decompose than sawdust used in our experiment. In our experiment the lowest amount of protein contained fruiting bodies of *A. polytricha*, only 6.66 %, which is generally much higher than reported by Mau et al [15] – 5.7 %. General investigation on amount of crude protein in *Auricularia* species showed range only from 4.2 % up to 5.52 % of dry matter in *A. auricula-judae* [4, 9]. Both strains of *L. edodes* contained similar amount of protein in fruiting bodies (14.73 % in 'SH27' and 14.48 % in 'SH37'), however 'SH27' tend to contain higher amount of protein (Fig. 1). Those amounts are comparable with results obtained by

Table 1

Chemical compositions of dried fruiting bodies of some mushrooms species and strains

Constituent	Kind of sawdust	*Lentinula edodes*		*Pleurotus eryngii*		*Auricularia auricula-judae*	*Auricularia polytricha*
		SH 37	SH 27	B124	B127		
		[%]					
Water	AS	8.10 ± 0.62 a	7.91 ± 0.28 a	10.82 ± 0.43 *a*	10.12 ± 0.11 *a*	11.21 ± 0.31 A	10.80 ± 0.72 A
	BS	8.16 ± 0.17 a	8.20 ± 0.36 a	10.24 ± 0.62 *a*	10.64 ± 0.81 *a*	10.98 ± 0.14 A	11.06 ± 0.58 A
Protein (Nx4.38)	AS	15.06 ± 0.68 a	14.84 ± 0.77 a	17.87 ± 0.09 *a*	18.35 ± 0.41 *a*	10.24 ± 0.54 A	6.30 ± 0.04 C
	BS	13.91 ± 0.53 b	14.00 ± 0.06 b	16.21 ± 0.12 *b*	15.98 ± 0.54 *b*	8.99 ± 0.41 B	7.03 ± 0.25 C
Fat	AS	2.60 ± 0.19 a	2.41 ± 0.21 a	2.21 ± 0.06 *a*	2.11 ± 0.11 *a*	1.00 ± 0.13 A	0.93 ± 0.08 A
	BS	2.63 ± 0.07 a	2.54 ± 0.17 a	2.34 ± 0.31 *a*	1.98 ± 0.43 *a*	1.02 ± 0.03 A	0.90 ± 0.11 A
Carbohydrates	AS	65.00 ± 0.58 b	66.12 ± 0.18 b	58.93 ± 0.17 *b*	59.13 ± 0.25 *b*	79.71 ± 0.38 B	81.22 ± 0.07 B
	BS	68.52 ± 0.72 a	68.41 ± 0.21 a	60.87 ± 0.10 *a*	62.03 ± 0.34 *a*	82.11 ± 0.54 A	83.30 ± 0.73 A
Ash	AS	6.81 ± 0.37 a	7.00 ± 0.11a	5.10 ± 0.39 *a*	5.12 ± 0.25 *a*	3.46 ± 0.90 A	3.02 ± 0.17 B
	BS	6.56 ± 0.61 a	6.98 ± 0.09 a	4.96 ± 0.21*a*	5.09 ± 0.08 *a*	3.91 ± 0.01 A	2.87 ± 0.37 B

AS – beech sawdust; BS – birch sawdust; Significant differences in contents of analyzed substances in dried mushrooms are marked with different letters.

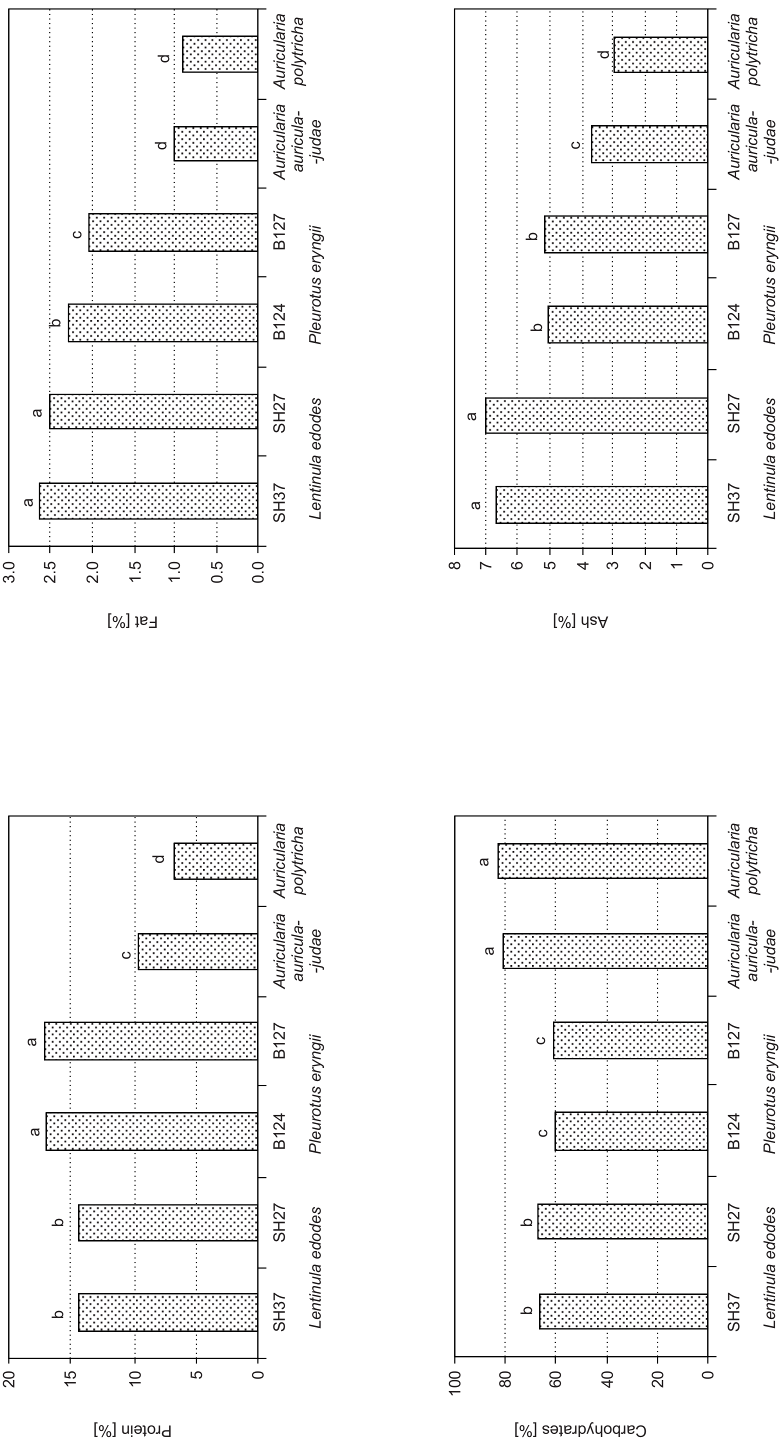

Fig. 1. Protein, fat, carbohydrates and ash content of dried fruiting bodies of some mushrooms species; Significant differences in contents of analyzed substances in dried mushrooms are marked with different letters

Chang and Miles [9] – 13.4–17.5 %, however much lower than those of later experiment by Regula and Siwulski [16] (17.2 %).

Mushrooms are shown to be low-fat products, and general content of crude fat in dry matter of *L. edodes* fruiting bodies according to many authors range from 1.3 % to 8.7 % [17, 18]. Two strains of *L. edodes* contained the highest value of crude fat (2.62 % in 'SH37' and 2.5 % in 'SH27') (Fig. 1) which is in accordance with investigation held by Regula and Siwulski [16] (2.89 %). *A. polytricha* contained the lowest amount of crude fat (0.92 %) and *A. auricula-judae* contained 1.01 % of crude fat, which is even lower than the results obtained by Shin et al [4] – 3.5 %. Lower fat contents are only noted by Mau et al (0.48 %) [15]. In the experiment conducted in 2008 by Dundar et al [14] the amount of fat content in *P. eryngii* was quite high (7.5 %), in our study the content of fat was much lower (2.28 % and 2.04 % in 'B124' and 'B127', respectively). Furthermore, those amounts are comparable with the results obtained by Cheung [13] (1.93 %).

The results of our studies showed that the carbohydrates contents ranged from 59.4 to 82.26 % in the following order: *P. eryngii*, *L. edodes*, *A. auricula-judae*, *A. polytricha* (Fig. 1). Other authors [4, 15, 19] report the carbohydrates content in *Auricularia* species range from 70 to 88 %. In our investigation the highest amount was observed in *A. polytricha* (82.26 %), which fits within the reported average. The lowest amount (59.4 %) of carbohydrates contained strain *P. eryngii* 'B124', however this was higher than noted in experiment carried out by Dundar et al [14] (39.85 %). In the earlier studies, Lasota and Sylwestrzak [17] reported the total carbohydrates content in fruiting bodies of *L. edodes* range from 30–38 %. Later, Regula and Siwulski [16] obtained in their experiment much higher content of carbohydrates, up to 66 %. This amount is similar to amount of carbohydrates obtained in our experiment.

The ash contents in the carpophores of investigated mushrooms was the highest in *L. edodes* and differed between strains, where the average amount of ash in 'SH27' was higher than in 'SH37' (6.99 % and 6.68 %, respectively) (Fig. 1). Those amounts are similar to those obtained by other authors [9, 16, 18]. The lowest amount of ash contained *A. polytricha* (2.94 %), regardless to the cultivation substrates, which is comparable with results obtained by Mau et al [7] – 2.5 %. It can be explained that the mushrooms with pileus and stipe tend to had higher level of ash compared with those without stipe [20, 21]. The content of ash in fruiting bodies of both strains of *P. eryngii* in our investigation ranged from 5.03 % to 5.1 % for 'B124' and 'B127', respectively and is comparable with earlier experiments conducted by Cheung [13] (5.18 %) and Dundar et al [14] (4.89 %).

The differences between the chemical compositions of mushrooms investigated in this study can of course be caused by use of different growing substrate, morphogenetic differences between the species and special individual character of the selected species and strains. The biological efficiency of the substrate is one of the key factors here.

For the reason that data on the nutritive value of described mushrooms grown on common and cheap substrates such as: wheat straw, beech or birch sawdust are limited in Poland, there is a strong need of conducting further experiments.

Conclusions

1. Cultivation substrates influenced chemical composition of fruiting bodies of investigated mushrooms, especially the content of protein and carbohydrates. Higher amount of protein was noted in fruiting bodies of mushrooms cultivated on beech sawdust, while carbohydrates content was higher on birch sawdust substrate.

2. The fruiting bodies of tested mushroom species differed in content of protein, carbohydrates, fat and ash. Fruiting bodies of *P. eryngii* contained the highest amount of protein; while fruiting bodies of *L. edodes* had the highest content of fat and ash. The highest amount of carbohydrates was observed in fruiting bodies of *Auricularia* genus.

References

[1] Tu C.-C., and Wu K-T.: [in:] Proc. of the Seventh Sympos. on Edible Fungi Research and Improvement of Production, Taiwan Agriculture Research Institute Ed. 1989, 137–142.
[2] Sadler M.: Brit. Nutr. Found. Nutr. Bull. 2003, **28**, 305–308.
[3] Bano Z. and Rajarathnam S.: [in:] Tropical mushrooms: Biological nature and cultivation methods. S.T. Chang and T.H. Quimio (eds.), Hong Kong, The Chinese University Press, 1982, pp. 363–380.
[4] Shin C.K., Yee C.F., Shya L.J. and Atong M.: J. Appl. Sci. 2007, **7**(15), 2216–2221.
[5] Chang S.T., Lau O.W. and Cho K.Y.: J. Appl. Microbiol. Biotechnol. 1981, **12**, 58–62.
[6] Crisan E.V. and Sands A.: The biology and cultivation of edible mushrooms. Academic Press, London 1978, pp. 137–168.
[7] Oei P.: Mushroom Cultivation. Backhuys Publishers, Leiden, Netherlands 2003.
[8] Rutkowska U.: Wybrane metody badania składu i wartości żywności. PZWL, Warszawa 1981.
[9] Chang S.T. and Miles D.G.: Edible mushrooms and their cultivation. CRS Press, Boca Raton, FL., USA 1989, p. 27–40.
[10] Chang S.T. and Buswell J.A.: World J. Microb. Biotechnol. 1996, **12**, 473–476.
[11] Chang S.T. and Mshigeni K.E.: Mushroom and their human health: their growing significance as potent dietary supplements. The University of Namibia Ed., Windhoek 2001, p. 1–79.
[12] Breene W.M.: J. Food Protect. 1990**, 53**(10), 883–894.
[13] Cheung P.C.K. (ed.): Mushroom as functional foods. John Wiley & Sons, Inc. 2008, p. 81–82.
[14] Dundar A., Acay H. and Yildiz A.: African J. Biotechnol. 2008, **7**(19), 3497–3501.
[15] Mau J.L., Wu K.T., Wu Y.H. and Lin Y.P.: J. Agric. Food Chem. 1998, **46**, 4583–4586.
[16] Reguła J. and Siwulski M.: Acta Sci. Polon., Technol. Aliment. 2007, **6**(4), 135–142.
[17] Lasota W. and Sylwestrzak J.: Bromatol. Chem. Toksykol. 1982, **22**(4), 167–171.
[18] Woźniak W. and Gapiński M.: Zesz. Nauk. ATR Bydgoszcz 1998, **42** (215), 257–260.
[19] Okwulehie I.C. and Odunze E.I.: J. Sustain. Agric. Environ. 2004, **6**, 157–162.
[20] Alofe F.V., Odeyemi O. and Oke O.L.: Plant Foods for Human Nutr. 1996, **49***,* 63–73.
[21] Latif L.A, Mohd Daran A.B. and Mohamed A.B.: Food Chem. 1995, **56**, 115–121.

PORÓWNANIE SKŁADU CHEMICZNEGO OWOCNIKÓW WYBRANYCH GRZYBÓW UPRAWIANYCH NA PODŁOŻU Z TROCIN

Katedra Warzywnictwa
Uniwersytet Przyrodniczy w Poznaniu

Abstrakt: Określono skład chemiczny owocników wybranych grzybów uprawnych: dwóch odmian *Lentinula edodes*; dwóch odmian *Pleurotus eryngii*, *Auricularia auricula-judae* oraz *A. polytricha.* Uprawę prowadzono na dwóch rodzajach trocin: brzozowych i bukowych. Określono zawartość białka, tłuszczu, węglowodanów oraz popiołu w owocnikach badanych grzybów.

Uzyskane wyniki wykazały wpływ rodzaju trocin na skład chemiczny owocników badanych gatunków i odmian grzybów jadalnych. Najwyższą zawartością białka charakteryzowały się owocniki *P. eryngii*, natomiast owocniki *L. edodes* zawierały największą ilość tłuszczu i popiołu. Owocniki grzybów z rodzaju *Auricularia* charakteryzowały się największą zawartością węglowodanów.

Słowa kluczowe: *Lentinula edodes*, *Pleurotus eryngii, Auricularia auricula-judae, Auricularia polytricha,* owocniki, skład chemiczny, trociny

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Sylwester SMOLEŃ[1] and Włodzimierz SADY[1]

EFFECT OF FERTILIZATION WITH ENTEC-26 AND AMMONIUM NITRATE ON THE CHANGES IN SELECTED CHEMICAL SOIL PROPERTIES AFTER CARROT CULTIVATION

WPŁYW NAWOŻENIA ENTEC-26 I SALETRĄ AMONOWĄ NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

Abstract: In the research carried out in 2004–2005 with carrot cultivation the following combinations were applied: 1 – Control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 +70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; where 35 + 35, 70 + 70 and 105 + 105 kg N · ha^{-1} denote nitrogen doses applied for presowing fertilization and top dressing, respectively. In case of ENTEC-26 [a fertilizer with nitrification inhibitor, 3,4-dimethylpyrazol phosphate (DMPP)], in both years of the research a tendency of lowering the content NH_4-N in both analyzed layers of the soil with increasing nitrogen dose was observed. These interrelations were not noted in case of fertilization with ammonium nitrate. In the individual years of the experiments nitrogen fertilization had a dissimilar effect of the content of NH_4-N, NO_3-N, Cd, Cu, Pb and Zn after the cultivation and percentage change of these chemical properties in the soil layers of 0–30 cm and 30–60 cm in relation to the values measured prior to carrot cultivation. No significant effect of applied fertilization on soil reaction (pH) was noted.

Keywords: nitrogen leaching, nitrification inhibitor, 3,4-dimethylpyrazol phosphate (DMPP), heavy metals

One of the negative consequences of using chemical nitrogen fertilizers is the process of leaching NO_3-N from soil into groundwater [1]. This process is less intensive when applying fertilizers containing reduced forms of N (NH_4-N and NH_2-N) present in physiologically acid fertilizers. However, in the soil process of nitrification these forms are oxidized (after initial transformation from NH_2-N into NH_4-N) into NO_3-N form, which is susceptible to leaching [2]. One possibility of stabilizing reduced forms of N in soil is the use of nitrification inhibitors [3–5]. A negative aspect of applying physiologically acid fertilizers may be a decrease in soil pH value what contributes to an increase of the content of heavy metals forms available for plants [6].

[1] Department of Soil Cultivation and Fertilization of Horticultural Plants, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 5239, fax: +48 12 662 5240, email: ssmolen@ogr.ur.krakow.pl; wjsady@ogr.ur.krakow.pl

The aim of our research was to determine the effect of doses and time of ENTEC-26 application [7.5 % NO_3-N, 18.5 % NH_4-N, 13 % SO_4-S and nitrification inhibitor 3,4-dimethylpyrazol phosphate (DMPP)] in comparison with fertilization with ammonium nitrate on the changes in selected chemical properties of soil after carrot cultivation.

Material and methods

The field experiment on carrot, 'Kazan F_1' cv., cultivation was conducted in 2004–2005 at Trzciana, each year on a different site within a single soil complex owned by a single horticultural farm. The carrot plants were cultivated in a three-year crop rotation composed of sugar beets 1st year, winter wheat 2nd year and carrot 3rd year. The seeds were sown on 24th April 2004 and 30th April 2005. The experiments were arranged in a split-plot design in four replications. The experiments comprised of the following treatments: 1 – Control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; where 35 + 35, 70 + 70 and 105 + 105 kg N · ha^{-1} denote nitrogen doses applied for presowing fertilization and top dressing, respectively.

Soils samples from two layers: 0–30 cm and 30–60 cm were taken in spring before the experiment outset as well as during carrot harvesting (24th September 2004 and 8th September 2005). During carrot harvesting soil samples were collected for each nitrogen fertilization treatment. Methods of soil analysis included assessment of: soil texture using Casagrande method modified by Pruszynski, organic matter content with Tiurin method modified by Oleksynowa and pH in H_2O determined potentiometrically (1 : 2, soil : H_2O volumetric ratio). Contents of NH_4-N and NO_3-N forms of mineral nitrogen in soil (after extraction with 0.03 mol · dm^{-3} CH_3COOH) were determined using the microdistillation method. Contents of Cd, Cu, Pb and Zn (after extraction with 0.01 mol · dm^{-3} $CaCl_2$) were determined by AAS technique.

The results of physical chemical properties of soil prior to carrot cultivation are presented in Table 1, while climatic conditions during the experimental period are shown in Table 2.

Table 1

Physical and chemical characteristics of soil layers 0–30 and 30–60 cm prior to experiment in 2004–2005

Characteristics	2004		2005	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm
Soli texture class	Silty clay	Silty clay	Silty clay	Silty clay
Organic matter [%]	2.20	1.33	2.26	1.50
pH_{H2O}	7.80	7.75	7.55	7.70
NH_4-N [mg · dm^{-3}]	12.3	10.5	21.0	7.0
NO_3-N [mg · dm^{-3}]	33.3	35.0	33.3	21.0
Cd [mg · kg^{-1}]	0.09	0.07	0.18	0.06
Cu [mg · kg^{-1}]	3.35	3.75	0.23	0.11
Pb [mg · kg^{-1}]	2.22	2.23	0.13	0.03
Zn [mg · kg^{-1}]	8.11	5.05	1.08	0.16

Table 2

Meteorological data for the region where experiment was conducted (Rzeszow-Jasionka, Poland – 50°05′ N, 21°98′ E) during the period of experiment

Specification for growth period and years	Year 2004			Year 2005		
	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]
April	8.7	72.5	237.1	9.1	48.4	189.9
May	12.3	40.9	242.1	13.9	105.1	264.5
June	16.5	64.3	254.4	16.8	109.6	296.6
July	18.5	179.6	272.5	19.8	109.1	291.5
August	18.4	98.8	256.0	17.5	123.9	224.2
September	13.3	22.5	210.9	14.8	62.4	242.0
Mean for growth period	14.6	79.8	245.5	15.3	93.1	251.5
Sum for growth period	—	558.4	1718.5	—	651.6	1760.2
Mean for year of study*	8.5	742.0	2012.0	8.3	774.0	2106.0
Mean for 1951–2005	8.1	642	1846.4**	—	—	—

* Data for Rzeszow-Jasionka Poland from Concise Statistical Yearbook of Poland (2000, 2001, 2002, 2003, 2004, 2005, 2006), Polish Central Statistical Office, Warsaw, Poland; ** Sunshine only for 2001–2005.

Obtained results were verified statistically with the ANOVA module of 'Statistica 8.0 PL' for $p < 0.05$. The significance of differences was computed with Duncan test. A more detailed description of the experiments together with the results concerning the effect of fertilization on the quantity and quality of carrot yield have been published previously [7–9].

Results and discussion

It should be emphasized that with comparatively similar physical chemical characteristics of soil in both years of the experiments: soil texture class, content of organic matter and pH value (Table 1), higher rainfall in 2005 (especially in May, June, August and September) when compared with 2004 (Table 2) could have been the reason for lower soil content of NH_4-N and NO_3-N. What is more, that weather conditions could have contributed to demonstrated differences in size of change in the content of these forms of nitrogen in the layers 0–30 and 30–60 cm of soil after cultivation in comparison with initial values (Fig. 1 and 2). The results of analyses of NH_4-N and NO_3-N content in soil after cultivation, as well as size of changes in the content of both form of nitrogen in 0–30 and 30–60 cm soil layers before the outset of carrot cultivation demonstrate that the efficiency of DMPP nitrification inhibitor on stabilizing ammonium form of nitrogen in soil depended both on fertilizer dose and the course of climatic conditions during cultivation, with a particular emphasis on the amount and distribution of rainfall (Table 2). In 2005, unlike in 2004, there were no significant differences noted in the content of NH_4-N in both layers of soil.

Contrary to theoretical premises, in each year of fertilizing with ENTEC-26, there was a tendency of lowering the content of NH_4-N in both analyzed layers of soil along with increasing nitrogen dose accompanied by consequently higher dose of nitrification inhibitor. These interactions were not observed in case of fertilization with ammonium nitrate (Fig. 1). In 2004, the soil fertilized with ammonium nitrate as 70 + 70 and

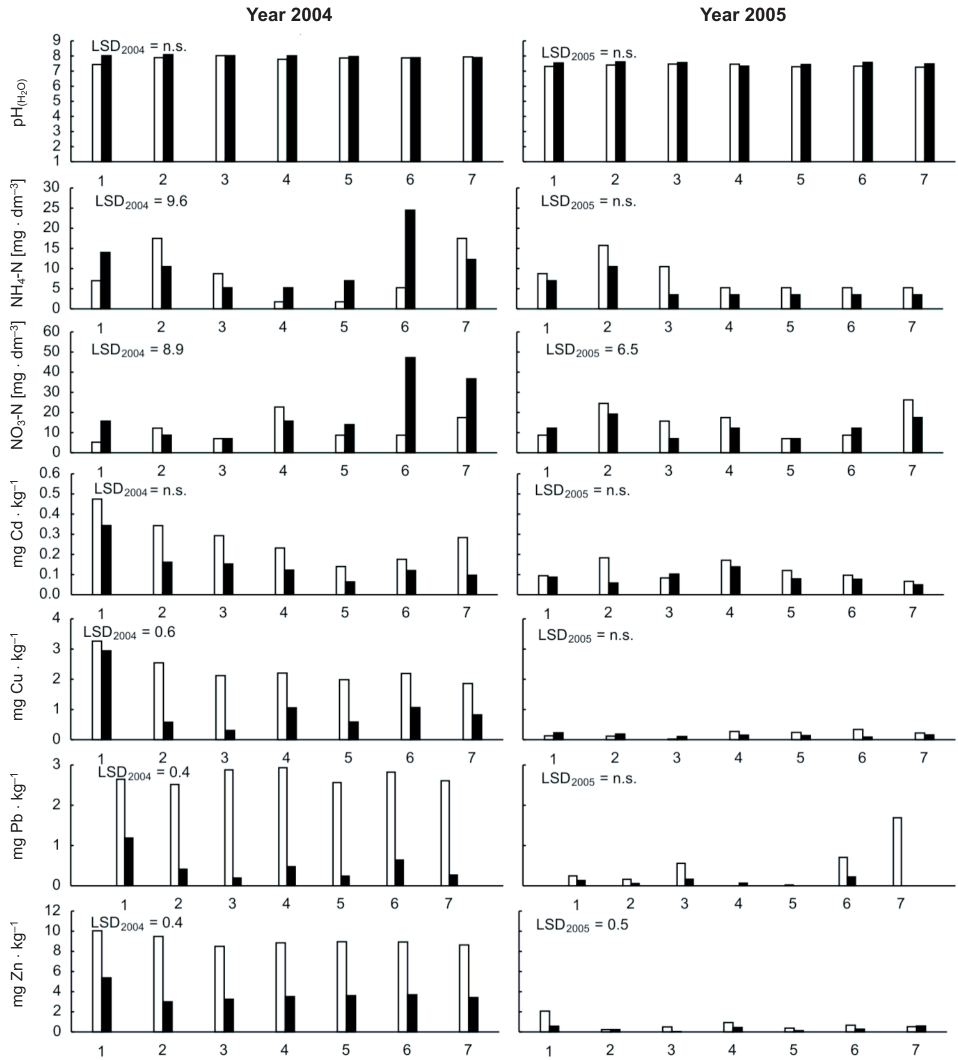

Fig. 1. Effect of nitrogen fertilization on soil reaction (pH) and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb in 0–30 and 30–60 cm soil layers after carrot cultivation in 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. not significant

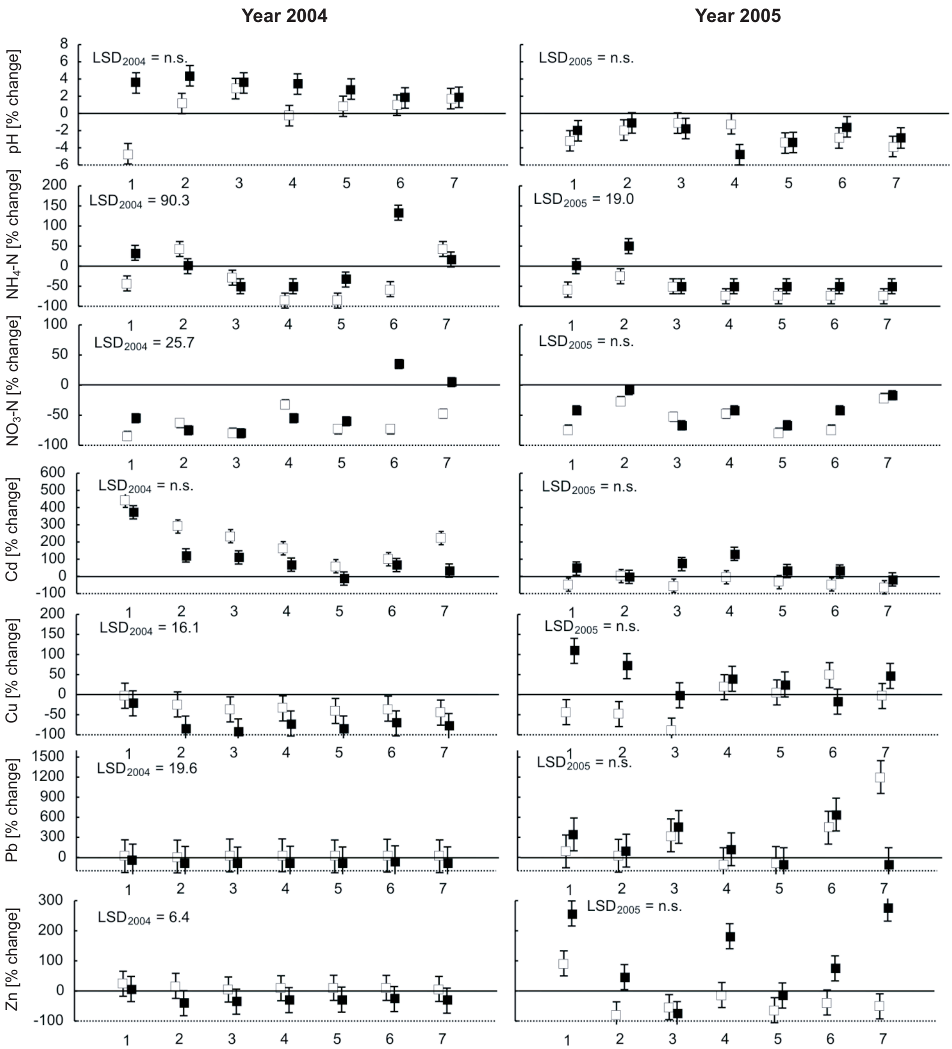

Fig. 2. Effect of nitrogen fertilization on size of changes [%] of chemical characteristics (pH and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb and Zn) in 0–30 and 30–60 cm soil layers after carrot cultivation as compared with the values measured prior to carrot cultivation in 2004 and 2005
Explanation: ☐ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

105 + 105 kg N · ha^{-1} was characterized by higher content of both forms of nitrogen (NH_4-N and NO_3-N) than the soil fertilized with ENTEC-26 in a similar manner. The relationships mentioned above are difficult to prove on the basis of knowledge about nitrogen transformation in soil environment. These results could have been insignificantly influenced by more effective plant uptake of nitrogen from ENTEC-26

rather than from ammonium nitrate, which has been demonstrated in an earlier work [9]. Study of Gioacchini et al [4] registered a distinct effect of ENTEC-26 on NH_4-N and NO_3-N contents in clay loam and sandy loam. These authors inform that nitrogen availability is, in fact, the end result of interactions between the added substances and the natural soil cycle.

Owing to their chemical characteristics, nitrogen fertilizers can affect soil pH value and, as a result, influence the availability of microelements and heavy metals for plants [6]. In the research by Zaccheo et al [10] 15-day incubation of $(NH_4)_2SO_4$ with DMPP as well as $Ca(NO_3)_2$ did not result in any significant changes in soil reaction as compared with strongly acidifying action of $(NH_4)_2SO_4$ and $(NH_4)_2S_2O_3$. Our research does not reveal any significant influence of doses and time of application of both physiologically acid nitrogen fertilizers on soil pH value or the content of easily soluble forms of Cd, as well as size of change in both these parameters in 0–30 and 30–60 cm layers of the soil after cultivation as compared with initial values (Fig. 1 and 2). In both years of the experiments we observed a differential effect of fertilization with nitrogen on the content of easily soluble forms of Cu, Pb and Zn in 0–30 cm and 30–60 cm layers of soil after cultivation and size of change of these elements in comparison with the values measured in soil before carrot cultivation. There was a significant effect of nitrogen fertilization on the content of Zn in both years of the experiments. Considerable differentiation in the content of Cu and Pb and percentage change in the content of Cu, Pb and Zn in 0–30 cm and 30–60 cm layers of soil in comparison with the initial values was noted in 2004 exclusively. When compared with the control, in both years of the experiments a decrease in the content of Zn as well as Cu in 2004 – was noted in both analyzed layers of soil from all combinations with nitrogen fertilization. Similar relationships were observed in 2004 in case of Pb but only in the layer 30–60 cm. In that year the content of Pb in 0–30 cm layer of soil from all combinations of the experiment was at a comparable level.

Higher amount of rainfall during carrot cultivation in 2005 (Table 2) resulting in an increased quantity of nitrogen leached from the soil (Fig. 1 and 2), caused a significantly shorter interaction of applied fertilizers on soil environment. In that year of the study, the results of Cd, Cu, Pb and Zn content analysis in soil after carrot cultivation indicate that nitrogen fertilizer only insignificantly influenced solubility degree of Cd, Cu, Pb and Zn in both analyzed layers of soil. There is a substantiated hypothesis that mobile fractions of these elements could have been leached to large extent by precipitation waters to soil layers deeper than 60 cm. However, previously published results of the effect of applied nitrogen fertilization on the content of Cd, Cu and Zn storage roots of carrot [7] demonstrated that in 2005 the content of Cd and Cu in carrot was much higher, and the content of Zn insignificantly lower than in 2004. Therefore, the effect of nitrogen fertilizers on the soil content of elements investigated in our research depended not only on their chemical characteristics but also on the physical and chemical properties of soil as well as the course of climatic conditions, with a special emphasis on the amount and distribution of rainfall during cultivation period.

Conclusions

1. In both years of the research, a tendency of higher nitrogen doses applied in the form of ENTEC-26 resulting in the decrease of the content of NH_4-N in 0–30 and 30–60 cm analyzed layers of the soil was observed.

2. Indirectly, a higher effectiveness of nitrification inhibitor DMPP (contained in ENTEC-26) on stabilizing the form NH_4-N in soil environment was noted in 2004, which was characterized by smaller rainfall during carrot cultivation than in 2005.

3. Neither of physiologically acid nitrogen fertilizer applied in the experiments (regardless of nitrogen dose) caused any decrease on soil pH value as well as had no influence on the content of easily soluble forms of Cd, Cu, Pb and Zn in soil.

References

[1] Spalding R.F. and Exner M.E.: J. Environ. Qual. 1993, **22**, 392–402.
[2] Gorlach E. and Mazur T.: Chemia rolna. Wyd. Nauk. PWN, Warszawa 2002 [in Polish].
[3] Hähndel R. and Wissemeier A.H.: [in:] ISHS Symposium Towards ecologically sound fertilization strategies for filed production. Italius Hort. 2004, **11**(3), p. 24.
[4] Gioacchini P., Ramieri N.A., Montecchio D., Marzadori C. and Ciavatta C.: Commun. Soil Sci. Plant Anal. 2006, **37**, 1–12.
[5] Kołota E., Adamczewska-Sowińska K. and Krężel J.: Veg. Crops Res. Bull. 2007, **67**, 47–54.
[6] Gębski M.: Post. Nauk Roln. 1998, **5**, 3–16.
[7] Smoleń S. and Sady W.: Ochr. Środow. i Zasob. Natur. 2007, **32**, 81–86.
[8] Smoleń S. and Sady W.: Hort. Sci. Biot. 2008, **83**, 427–434.
[9] Smoleń S. and Sady W.: Sci. Hort. 2009, **119**(3), 219–231.
[10] Zaccheo P. Crippa L. and Di Muzio Pasta V.: Plant Soil. 2006, **283**, 43–56.

WPŁYW NAWOŻENIA ENTEC-26 I SALETRĄ AMONOWĄ NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

Katedra Uprawy Roli i Nawożenia Roślin Ogrodniczych, Wydział Ogrodniczy
Uniwersytet Rolniczy w Krakowie

Abstrakt: Badania wykonano w latach 2003–2005. W uprawie marchwi zastosowano: 1 – kontrola (bez nawożenia azotem), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – saletrę amonową 35 + 35 kg N, 6 – saletrę amonową 70 + 70 kg N, 7 – saletrę amonową 105 + 105 kg N $\cdot$ ha^{-1}; gdzie 35 + 35, 70 + 70 i 105 + 105 oznacza dawkę azotu w kg N $\cdot$ ha^{-1} zastosowaną odpowiednio przedsiewnie i pogłównie.

W przypadku ENTEC-26 [nawóz z inhibitorem nitryfikacji 3,4-dimetylopyrazolofosfatem (DMPP)], w obydwu latach badań wraz ze wzrostem dawki azotu odnotowano tendencję do obniżenia zawartości NH_4-N w obydwu analizowanych warstwach gleby, natomiast nie stwierdzono takich zależności w przypadku nawożenia saletrą amonową. W poszczególnych latach prowadzenia badań wykazano odmienny wpływ nawożenia azotem na zawartość: NH_4-N, NO_3-N, Cd, Cu, Pb i Zn po uprawie oraz na wartości zamian tych parametrów w warstwach 0–30 cm i 30–60 cm gleby w stosunku do wartości zmierzonych przed rozpoczęciem uprawy marchwi. Nie stwierdzono istotnego wpływu zastosowanego nawożenia azotem na odczyn gleby (pH).

Słowa kluczowe: wymywanie azotu, inhibitor nitryfikacji, 3,4-dimetylopyrazolofosfat (DMPP), metale ciężkie

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Sylwester SMOLEŃ[1] and Włodzimierz SADY[1]

EFFECT OF NITROGEN FERTILIZERS ON THE CHANGE IN SELECTED CHEMICAL CHARACTERISTICS OF SOIL AFTER CARROT CULTIVATION

WPŁYW STOSOWANIA NAWOZÓW AZOTOWYCH NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

Abstract: In 2003–2005 in carrot cultivation the following combinations were applied (kg N · ha^{-1}): 1 – Control (without N fertilization), 2 – calcium nitrate 70, 3 – calcium nitrate 70 + 70, 4 – ammonium sulphate 70 and 5 – ammonium sulphate 70 + 70; where 70 means 70 kg N · ha^{-1} was used preplant, whereas 70 + 70 that 70 + 70 kg N · ha^{-1} was applied preplant and as a top dressing, respectively.

In the individual years of the research a diversified effect of nitrogen fertilization on the content of NH_4-N, NO_3-N, Cd, Cu, Pb and Zn and soil reaction (pH) after carrot cultivation, as well the size of changes in these chemical characteristics in 0–30 cm and 30–60 cm soil layers were noted when compared with the values measured prior to the start of carrot cultivation. Variable climatic conditions as well as rainfall amount and its distribution significantly influenced the content of mineral nitrogen in 0–30 and 30–60 cm layers of soil after carrot cultivation. In 2003, characterized by the lowest rainfall in the period of carrot cultivation and drought in the summer months, were noted the highest content of NH_4-N in 30–60 cm layer of soil fertilized with presowing and topdressing treatment of ammonium sulfate, and NO_3-N in 0–30 cm layer of soil fertilized with presowing and top dressing treatment of calcium nitrate.

Keywords: nitrogen leaching, heavy metals

One of the negative consequences of using chemical nitrogen fertilizers is the process of NO_3-N leaching from soil into groundwater [1]. Nitrogen losses are greater especially in case of applying fertilizer containing oxidized form of nitrogen (NO_3-N) when compared with those containing reduced form of N (NH_4-N and NH_2-N – present in physiologically acid fertilizers, eg urea and ammonium sulfate) [2]. Nevertheless, application of physiologically acid fertilizer can lead to lowering soil pH value, and consequently cause rise in the content of easily available forms of heavy

[1] Department of Soil Cultivation and Fertilization of Horticultural Plants, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 5239, fax: +48 12 662 5240, email: ssmolen@ogr.ur.krakow.pl; wjsady@ogr.ur.krakow.pl

metals in soil. This, in turn, can result in an increase in the content of those elements in yield [3].

This research aimed at determining the effect of calcium nitrate (physiologically alkaline fertilizer) and ammonium sulfate application diversified with regards to dose and time on the change in selected properties of soil after carrot cultivation.

Material and methods

The field experiment on carrot, 'Kazan F_1' cv., cultivation was conducted in 2003–2005 at Trzciana, each year on a different site within a single soil complex owned by a single horticultural farm. The carrot plants were cultivated in a three-year crop rotation composed of sugar beets 1st year, winter wheat 2nd year and carrot 3rd year. The seeds were sown on 28th April 2003, 24th April 2004 and 30th April 2005. The experiments were arranged in a split-plot design in four replications. Experiment comprised of the following treatments (kg N · ha^{-1}): 1 – control (without N fertilization), 2 – calcium nitrate 70, 3 – calcium nitrate 70 + 70, 4 – ammonium sulphate 70 and 5 – ammonium sulphate 70 + 70; where 70 means 70 kg N · ha^{-1} was used preplant, whereas 70 + 70 that 70 + 70 kg N · ha^{-1} was applied preplant and as a top dressing, respectively. Presowing nitrogen fertilization was conducted immediately before bed formation, whereas top dressing was performed at canopy closure (16th June 2003, 1st July 2004 and 30th June 2005).

Table 1

Physical and chemical characteristics of soil layers 0–30 and 30–60 cm prior to the start of experiment in 2003–2005

Characteristics	2003		2004		2005	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm	0–30 cm	30–60 cm
Soli texture class	Clay loam	Clay	Silty clay	Silty clay	Silty clay	Silty clay
Organic matter [%]	3.92	2.52	2.20	1.33	2.26	1.50
pH_{H2O}	7.03	7.52	7.80	7.75	7.55	7.70
NH_4-N [mg · dm^{-3}]	8.8	7.0	12.3	10.5	21.0	7.0
NO_3-N [mg · dm^{-3}]	15.8	15.8	33.3	35.0	33.3	21.0
Cd [mg · kg^{-1}]	0.28	0.06	0.09	0.07	0.18	0.06
Cu [mg · kg^{-1}]	4.38	3.60	3.35	3.75	0.23	0.11
Pb [mg · kg^{-1}]	3.08	1.97	2.22	2.23	0.13	0.03
Zn [mg · kg^{-1}]	11.03	6.92	8.11	5.05	1.08	0.16

Soils samples from two layers: 0–30 cm and 30–60 cm were taken in spring before the experiment outset as well as during carrot harvesting (15th September 2003, 24th September 2004 and 8th September 2005). At carrot harvesting, average mixed sample was collected from four sites of every combination. Methods of soil analysis included assessment of: soil texture using Casagrande method modified by Pruszynski,

Table 2

Meteorological data for the region where experiment was conducted (Rzeszow-Jasionka, Poland – $50^{o}05'$ N, $21^{o}98'$ E) during the period of experiment

Specification for growth period and years	Year 2003			Year 2004			Year 2005		
	Average air temperature [^{o}C]	Rainfall [mm]	Sunshine [h]	Average air temperature [^{o}C]	Rainfall [mm]	Sunshine [h]	Average air temperature [^{o}C]	Rainfall [mm]	Sunshine [h]
April	7.4	51.0	233.1	8.7	72.5	237.1	9.1	48.4	189.9
May	16.5	93.6	279.3	12.3	40.9	242.1	13.9	105.1	264.5
June	18.0	75.4	324.8	16.5	64.3	254.4	16.8	109.6	296.6
July	19.5	62.8	269.3	18.5	179.6	272.5	19.8	109.1	291.5
August	19.7	17.3	320.8	18.4	98.8	256.0	17.5	123.9	224.2
September	13.8	43.2	235.5	13.3	22.5	210.9	14.8	62.4	242.0
Mean for growth period	15.8	57.2	277.1	14.6	79.8	245.5	15.3	93.1	251.5
Sum for growth period	—	400.5	1939.9	—	558.4	1718.5	—	651.6	1760.2
Mean for year of study*	8.3	521.0	2226.0	8.5	742.0	2012.0	8.3	774.0	2106.0
Mean for 1951–2005									
	—	—	—	8.1	642	1846.4**	—	—	—

* Data for Rzeszow-Jasionka Poland from Concise Statistical Yearbook of Poland (2000, 2001, 2002, 2003, 2004, 2005, 2006), Polish Central Statistical Office, Warsaw, Poland; ** Sunshine only for 2001–2005.

organic matter content with Tiurin method modified by Oleksynowa and pH in H_2O potentiometrically (1 : 2, soil: H_2O volumetric ratio). Contents of NH_4-N and NO_3-N forms of mineral nitrogen in soil (after extraction with 0.03 mol $\cdot$ dm^{-3} CH_3COOH) were determined using the microdistillation method. Contents of Cd, Cu, Pb and Zn (after extraction with 0.01 mol $\cdot$ dm^{-3} $CaCl_2$) were determined by AAS technique. The results of physical chemical properties of soil prior to carrot cultivation are presented in Table 1, while climatic conditions during the experimental period are shown in Table 2.

The obtained results were verified statistically with the ANOVA module of 'Statistica 8.0 PL' for $p < 0.05$. The significance of differences was computed with Duncan test.

A more detailed description of the experiments (eg chemical characterization of soil in each year of the study) together with the results concerning the effect of fertilization on the quantity and quality of carrot yield have been presented in earlier works [4, 5].

Results and discussion

The lower rainfall during carrot cultivation in 2003, when compared with the years 2004–2005 (Table 2) could have been the reason for a decrease in leached NO_3-N from both analyzed soil samples (Fig. 1 and 2) originating from applied fertilization as well as soil mineralization of organic matter. This is corroborated by the research of other authors [6, 7]. In that year, in 0–30 cm layer of soil fertilized with calcium nitrate dosed as 70 + 70 kg N $\cdot$ ha^{-1} the highest content of NO_3-N was noted in comparison with other combinations. Similarly, this combination revealed the highest growth in content of NO_3-N in the mentioned layer of soil in relation to its content prior to carrot cultivation. In the other two years (2004–2005), considerably higher amount of rainfall during cultivation could have caused intensified nitrogen leaching to soil layers deeper than 60 cm. In these years, both examined soil layers did not differ significantly in the content of NO_3-N with regards to nitrogen dose. Moreover, size of changes in the NO_3-N content in soil after carrot cultivation in relation to its initial content was of negative value, which was not noted in 2003. Research by Westerveld et al [8] revealed that during harvesting carrot cultivated both on mineral and organic soil, the highest content of NO_3-N (in all sites fertilized with nitrogen) was present in 0–30 cm soil layer rather than in deeper layers, 30–60 and 60–90 cm. These authors analyzed the content of NO_3-N and NH_4-N in individual layers of soil only in the last year of their three-year research cycle and carrot was grown for three years on the same field.

Information presented by Gorlach and Mazur [2] indicated that ions NH_4^+, as opposed to NO_3^-, after their introduction into soil with fertilizers containing NH_4-N, are absorbed by sorption complex to larger degree than leached to the deeper layers of soil. In our study, despite the lack of statistical differences between the combinations in the content of NH_4-N in soil (Fig. 1 and 2) it should be emphasized that in 2003 after carrot cultivation in 30–60 cm layer of soil fertilized with ammonium sulfate dosed as 70 + 70 kg N $\cdot$ ha^{-1}, the highest content of this form of nitrogen as well as statistically highest increase in percentage content of NH_4-N were observed when compared with its content

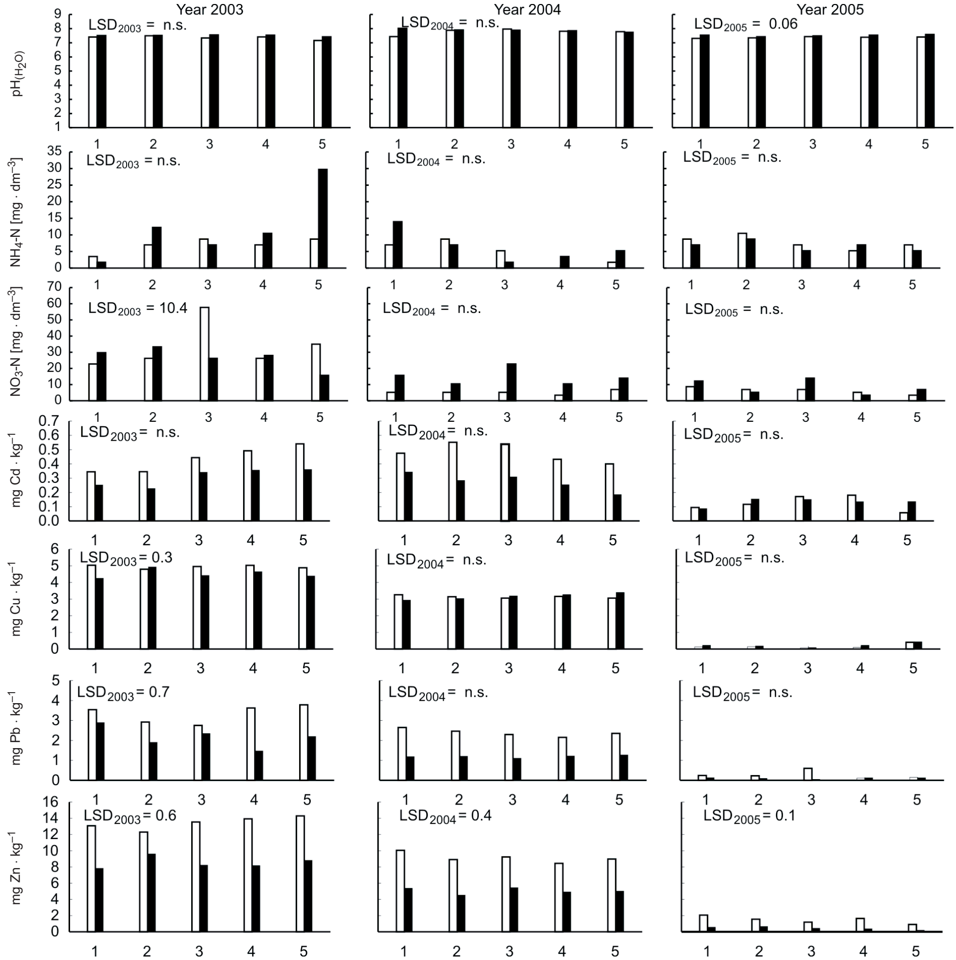

Fig. 1. Effect of nitrogen fertilization on soil reaction (pH) and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb in 0–30 and 30–60 cm soil layers after carrot cultivation in 2003, 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – calcium nitrate 70 kg N, 3 – calcium nitrate 70 + 70 kg N, 4 – ammonium sulphate 70 kg N and 5 – ammonium sulphate 70 + 70 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

in soil prior to carrot cultivation. It is difficult to interpret such a interrelation. Study by Sweeney and Granade [9] showed that fertilization with $(NH_4)_2SO_4$ increased the levels of extractable SO_4^{2-} in the soil, especially in layers deeper than 15 cm. It is possible that in our study SO_4^{2-} ions contained in ammonium sulfate were leached to 30–60 cm soil layer, especially after applied top dressing treatment. During the period of drought in the summer months that process could have been inhibited. Under the conditions of elevated concentration of SO_4^{2-} in 30–60 cm soil layer, these ions could have been fixing with NH_4^+ ions created in the process of soil mineralization of organic matter. The drought (in July, August and the beginning of September 2003) combined with

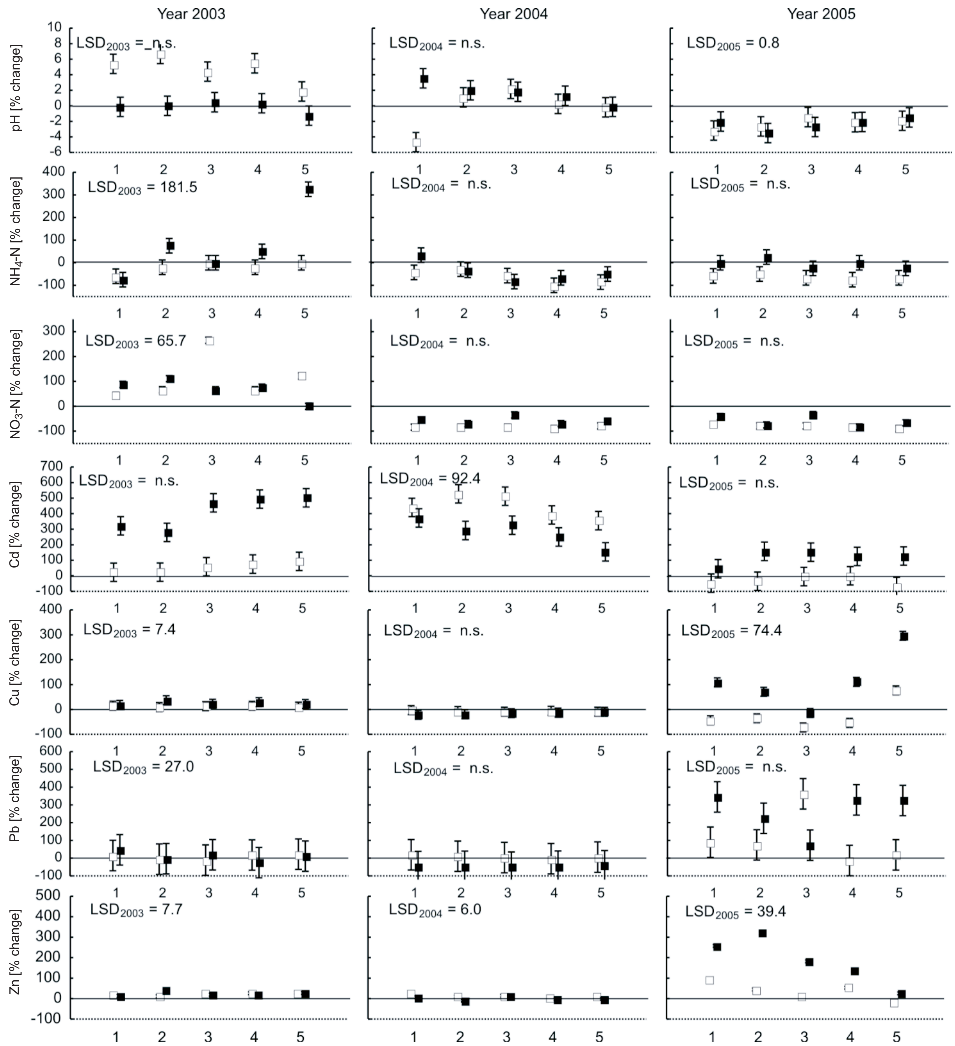

Fig. 2. Effect of nitrogen fertilization on size of changes [%] of chemical characteristics (pH and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb and Zn) in 0–30 and 30–60 cm soil layers after carrot cultivation as compared with the values measured prior to the start of carrot cultivation in 2003, 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – calcium nitrate 70 kg N, 3 – calcium nitrate 70 + 70 kg N, 4 – ammonium sulphate 70 kg N and 5 – ammonium sulphate 70 + 70 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

elevated temperature of soil could have additionally contributed to stabilizing NH_4^+ in soil environment due to weakened process of nitrification [2].

In individual years of the experiment was noted a significant effect of applied nitrogen fertilization particularly on the content of Zn in both analyzed layers of soil (Fig. 1 and 2). However, the influence of nitrogen fertilization on the soil pH and the content of Cd, Cu and Pb in individual layers of soil was relatively insignificant. In

2003 the highest content of Zn in 0–30 cm soil layer was noted after presowing and top dressing treatment with ammonium sulfate, and after presowing treatment in 30–60 cm layer in case of soil fertilized with calcium nitrate. In 2004–2005 the highest level of Zn in 0–30 cm layer was revealed in the soil from control site, and in case of 30–60 cm layer of the soil fertilized with calcium nitrate after presowing and top dressing in 2004 and only presowing in 2005. It should be emphasized that after carrot cultivation in 2005, in comparison with 2003–2004, we noted a relatively high increase in percentage content of Pb and Zn forms soluble in 0.01 mol $\cdot$ dm^{-3} $CaCl_2$ both in 0–30 cm and 30–60 cm and Cu in 30–60 cm soil layer. We did not note these dependencies in case of Cd. It is further worth noting that despite a dissimilar influence of nitrogen fertilization on the content of Cd, Cu, Pb and Zn as well as soil pH after cultivation (and size of changes of these parameters in relation to the values measured prior to the cultivation) we did not found any significant effect of research factors on the content of these elements in carrot storage roots in all years of the experiments [4].

Conclusions

1. Variable climatic conditions, and rainfall amount and its distribution, significantly influenced the content of mineral nitrogen in 0–30 and 30–60 cm layers of soil after carrot cultivation.

2. In 2003, characterized by the lowest rainfall in the period of carrot cultivation and drought in the summer months, we noted the highest content of NH_4-N in 30–60 cm layer of soil fertilized with presowing and topdressing treatment of ammonium sulfate, and NO_3-N in 0–30 cm layer of soil fertilized with presowing and top dressing treatment of calcium nitrate.

3. Diversified effect of nitrogen fertilization on soil pH value and the content of Cd, Cu, Pb and Zn in 0–30 and 30–60 cm soil layers after carrot cultivation was revealed in individual years of the research.

Acknowledgements

Experiment in 2003–2004 was financed by Alima-Gerber Enterprise. This research was co-financed by the Polish Ministry of Science and Higher Education as a part of Ph.D. Project No. 2 P06R 022 28, implemented in 2005–2006.

References

[1] Spalding R.F. and Exner M.E.: J. Environ. Qual. 1993, **22**, 392–402.
[2] Gorlach E. and Mazur T.: Chemia rolna. Wyd. Nauk. PWN, Warszawa 2002 [In Polish].
[3] Gębski M.: Post. Nauk Roln. 1998, **5**, 3–16.
[4] Smoleń S. and Sady W.: Polish J Environ. Stud. 2006, **15**(2A, Part II), 503–509.
[5] Smoleń S. and Sady W.: J. Hort. Sci. Biot. 2008, **83**, 427–434.
[6] Beaudoin N., Saad J.K., Van Laethem C., Machet J.M., Maucorps J. and Mary B.: Agric. Ecosyst. Environ. 2005, **111**, 292–310.
[7] Bakhsh A., Kanwar R.S., Pederson C. and Bailey T.B.: Water Air Soil Pollut. 2007, **181**, 35–50.
[8] Westerveld, S.M., Mc Keown A.W. and Mc Donald M.R.: Can. J. Plant Sci. 2006, **86**, 1227–1237.
[9] Sweeney D.W. and Granade G.V.: J. Plant Nutr. 1993, **16**, 1083–1098.

WPŁYW STOSOWANIA NAWOZÓW AZOTOWYCH NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

Katedra Uprawy Roli i Nawożenia Roślin Ogrodniczych, Wydział Ogrodniczy
Uniwersytet Przyrodniczy w Krakowie

Abstrakt: Badana wykonano w latach 2003–2005. W uprawie marchwi zastosowano (kg N · ha^{-1}): 1 – kontrola (bez nawożenia azotem), 2 – saletra wapniowa 70, 3 – saletra wapniowa 70 + 70, 4 – siarczan amonu 70, 5 – siarczan amonu 70 + 70; gdzie 70 oznacza 70 kg N · ha^{-1} zastosowane przedsiewnie, podczas gdy 70 + 70 odpowiednio 70 + 70 kg N · ha^{-1} azot zastosowany przedsiewnie i pogłównie.

W poszczególnych latach prowadzenia badań wykazano odmienny wpływ nawożenia azotem na zawartość: N-NH_4, N-NO_3, Cd, Cu, Pb i Zn, jak i na odczyn gleby (pH) po uprawie oraz na zakres zmian tych właściwości w warstwach 0–30 i 30–60 cm gleby w stosunku do wartości zmierzonych przed rozpoczęciem uprawy marchwi. Zróżnicowane warunki klimatyczne, ilość i rozkład opadów, miały znaczny wpływ na zawartość azotu mineralnego w 0–30 i 30–60 cm warstwach gleby po uprawie marchwi. W roku 2003 charakteryzującym się najmniejszą ilością opadów w okresie uprawy marchwi oraz suszą w miesiącach letnich stwierdzono największą zawartość N-NH_4 w 30–60 cm warstwie gleby nawożonej przedsiewnie i pogłównie siarczanem amonu, a N-NO_3 w 0–30 cm warstwie gleby nawożonej przedsiewnie i pogłównie saletrą wapniową.

Słowa kluczowe: wymywanie azotu, metale ciężkie

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Anna SZOPIŃSKA[1] and Maria GAWĘDA[2]

COMPARISON OF CARROT QUALITY CULTIVATED USING CONVENTIONAL, INTEGRATED AND ORGANIC METHOD

PORÓWNANIE JAKOŚCI MARCHWI UPRAWIANEJ METODAMI KONWENCJONALNĄ, INTEGROWANĄ I EKOLOGICZNĄ

Abstract: The experiment was conducted in the years 2006–2008 according to the rules of conventional, integrated and organic methods. Organic cultivation was conducted on a certified organic farm. The investigation focused on carrots 'Flakkee 2' cv. On the basis of average results for the three years of the experiment there was made an assessment of the effect of cultivation method on the quantity and quality parameters of yield, such as average mass of marketable roots, their length and diameter, and content of dry mass, nitrates, soluble sugars, ascorbic acid and carotenoids.

The total yield, mass and length of roots were bigger in organic cultivation. Carrot dry mass content did not differ significantly between yields coming from different cultivation systems. Nitrates contents in the analyzed roots were low constituting 25.5–55.8 % of the admissible norm. The highest amounts were noted in the roots from integrated cultivation. Significantly lower soluble sugar content was also revealed in the roots from the integrated system in comparison with carrots from the other cultivation systems. No differences in ascorbic acid or carotenoid content were shown in carrot roots coming from farms using different cultivation methods.

Keywords: carrots, organic cultivation, integrated cultivation, conventional cultivation, yielding, root quality

Availability of food products on European markets, increasing prosperity of societies and intensification of various civilisation diseases induce consumers to pay attention to the quality of products for consumption. Nutritional value and safety of food products greatly depend on raw material quality. Factors conditioning plant raw product quality and the nutritional value of food manufactured from them include soil and climate, the state of the natural environment and manufacturing technology.

[1] Rzeszow School of Engineering and Economics, ul. Miłocińska 40, 35–232 Rzeszów, Poland, phone: +48 17 860 16 40 ext. 44, email: aszopinska@wsie.edu.pl

[2] Department of Vegetable Crops and Horticulture Economics, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 52 23, email: mgaweda@bratek.ogr.ar.krakow.pl

Products manufactured on organic farms are greatly popular. They are regarded as a source of increased content of vitamins, carotenoids and folic acid [1]. It is commonly known that they also contain considerable amounts of polyphenols which as secondary metabolites are produced in considerable quantities and protect plants against harmful pathogens [2]. Plant products coming from organic production are treated as the richest source of antioxidants [3]. Apart from fresh products such as fruit and vegetables, consumers reach for processed products of organic origin more and more frequently.

Organic products constitute an increasingly bigger portion of agricultural production in most countries. Also in Poland they are winning more and more symphatizers which can be noticed in the growing number of certified organic farms. The objective of organic farming is manufacturing food that promotes good health and well-balanced development of the plant and animal and world as well as of the human being [4].

Comparative research conducted on organic and conventional methods of cultivation in recent years did not provide any synonymous confirmation of a higher quality of products from organic plantations [5]. The differences between the obtained results are ascribed to different factors of the conducted experiments, such as: variety of cultivars, climatic and soil conditions, as well as the date and stage of plant harvest. Conducted analyses of vitamin C content being an important indicator of plant product quality revealed that its concentration was higher or comparable in organic products than in conventional ones [6].

The rule of well-balanced production, being currently promoted in agriculture makes farmers introduce the rules of integrated cultivation. Vegetable exports, wholesale and retail sales or sales for the needs of processing industries will be impossible without the appropriate certificate. Comparison of many vegetable plants conducted by Faller et al [2] showed 10–35 % decrease in yields and increase in dry mass content in case of vegetables from organic cultivation in relation to those from integrated production. No differences in vitamin C content, nitrates or in a majority of macro- and microelements were revealed. However, the results of conducted experiments are not synonymous with these obtained by Woese et al [7] or Leclerc et al. [8]. There is still need for reliable information concerning the real quality of products originating from organic and integrated production as compared with those produced using traditional methods.

Material and methods

The analyses, conducted in three subsequent years 2006, 2007 and 2008, covered ‘Flakke 2’ cv. carrots cultivated according to rules of organic, integrated and conventional production. Organic cultivation was maintained on a certified organic farm which fulfilled the requirements of EC Regulation 2092/91 [9]. The farm is located in the Wisniowa rural district in the Podkarpackie province. It possesses acid brown soils with 2.39 % humus content as well as silt and clay parts constituting 71.74 % of the granulometric composition. The integrated and conventional cultivations were conducted on neighbouring farms with similar soil conditions. Distribution of experimental plantations at small distances from one another allowed to eliminate differences in climatic conditions.

In each method of cultivation the plants were sown in the third year after farmyard manure. The forecrops were root crops followed by cereals. Mineral fertilizers as supplementary treatment were applied in spring in conventional and integrated cultivations, whereas in organic cultivation slurry and certified fertilizers were used.

Minerals were maintained on the following levels: 50–70 mg $N \cdot dm^{-3}$, 40–60 mg $P \cdot dm^{-3}$, 120–170 mg $K \cdot dm^{-3}$, 60–70 mg $Mg \cdot dm^{-3}$, 1500–2000 mg $Ca \cdot dm^{-3}$.

Carrots cultivation, irrespective of the method was conducted on low ridge beds using a single row sowing. Thinning was done every 2–3 cm at the phase of 2–4 true leaves.

In organic cultivation weeds were controled mechanically. Diseases and insect pests prevention was carried out on the strength of natural substances admitted to be used in organic agriculture.

In the integrated method weeds were removed chemically and mechanically. The first spraying after sowing was made on dicotyledonous weeds, the second on unicotyledonous ones. The other weed control measures were done mechanically. Diseases and pests were fighted against when necessary.

The conventional method used exclusively chemical protection.

Immediately after harvest root mass, their length and diameter were determined and the following analyses were performed: content of dry mass was assessed using dryer method at 65 ^{o}C, soluble sugars using anthrone method [10], nitrate by means of ion selective electrode [11], carotenoids in acetone extracts (80 %) using Lichtenthaler--Wellburn formulas [12] and ascorbic acid content by means of iodine method [13].

The obtained results were evaluated using Statistica programme by means of variation analysis according to LSD test at significance level $p = 0.05$.

Results and discussion

The course of meteorological conditions in the subsequent vegetation seasons was diversified. Year 2006 was characterized by mean air temperature accounting for 8.7 ^{o}C. The average temperature in May was 13.5 ^{o}C, in July 17 ^{o}C and in August 21.3 ^{o}C. In the same years rainfall in May was 106 mm, in June 91 mm, in July 16 mm and in August 104 mm.

The year 2007 was characterized by a uniform temperature and rainfall distribution during the vegetation season. Average temperatures from May to September were respectively: 15.6 ^{o}C, 18.9 ^{o}C, 20.0 ^{o}C, 19.1 ^{o}C and 12.5 ^{o}C, whereas the rainfall amounted: 40 mm, 71 mm, 74 mm, 88 mm and 142 mm.

In 2008 the air temperatures were lower than in the previous season, respectively from May to September: 13.6 ^{o}C, 18.0 ^{o}C, 18.7 ^{o}C, 18.9 ^{o}C and 13 ^{o}C. The rainfall in May was 105 mm, in June 87 mm, in July 118 mm and in August 55 mm. The years 2006 and 2008 were similar concerning the course of meteorological conditions.

The results referring to yield quantity and carrot root parameters depending on the method of cultivation were presented in Table 1.

Significantly bigger total yield of carrot roots produced using organic method was revealed in comparison with the yields obtained by means of conventional and

Table 1

Carrot yielding and root parameters depending on cultivation method

Method	Total yield [kg · 10^{-2} · ha^{-1}]				Root mass [g]				Root length [cm]				Root diameter [cm]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	32.9 a*	25.45 a	26.98 a	**28.04 a**	109.29 n.s.**	138.85 a	90.05 a	**113.05 a**	15.06 n.s.	17.19 ab	14.18 n.s.	**15.51 a**	4.04 n.s.	4.41 n.s.	3.8 n.s.	**4.11 n.s.**
Integrated	32.82 a	29.69 ab	22.24 a	**28.25 a**	122.73 n.s.	305.66 b	111.29 a	**179.89 b**	13.92 n.s.	16.20 a	14.74 n.s.	**14.95 a**	3.88 n.s.	4.31 n.s.	4.10 n.s.	**4.10 n.s.**
Organic	45.78 b	35.64 b	38.32 b	**39.91 b**	140.31 n.s.	250.47 b	168.27 b	**186.35 b**	16.34 n.s.	18.25 b	16.84 n.s.	**17.14 b**	4.07 n.s.	4.23 n.s.	4.26 n.s.	**4.19 n.s.**
Average for years	**37.55 b**	**30.26 a**	**29.18 a**		**125.45 a**	**231.66 b**	**123.20 a**		**15.11 a**	**17.21 b**	**15.25 a**		**3.99 a**	**4.32 b**	**4.08 a**	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

integrated methods. Only in the second year of cultivation there were no differences between the organic and integrated methods.

In 2006 and 2008 carrot root length did not reveal any important differences conditioned by the method of cultivation. The longest roots were obtained in the second year of the experiments. Significantly shorter roots in comparison with organic carrots were produced using the integrated method in 2007. On the basis of three-year results it was demonstrated that carrots from organic cultivation produced the longest roots. No effect of cultivation method on carrot root diameter was revealed.

The causes of diversified yield quantity or carrot root parameters may be attributed to the influence of climatic conditions in the subsequent years. Intensive rainfalls at the initial period of cultivation in 2006 and 2008 contributed to a considerable soil compaction, whereas a lack of mechanical measures in the integrated and conventional method during the vegetation season prevented an improvement of the root growth conditions. Rainfall deficiencies occurring in summer (July 2006) and strong insolation might have caused slowing down of the growth rate. As was demonstrated by Krzesinski and Knaflewski [14] carrot root diameter is associated with average root mass and their length which is determined by the environmental conditions. Carrot roots are shorter if the air and soil temperatures are higher.

The quality of carrot roots was determined among others on the basis of dry matter and nitrates content assessments (Table 2). The method of cultivation did not affect root dry mass content in the first and third year of the analyses. In the second year the smallest content was determined in carrot roots cultivated using organic method. Roots coming from integrated cultivation did not differ with respect to dry matter content from the roots cultivated using conventional method. Comparison of results obtained in the subsequent years of cultivation showed the lowest content of dry matter in the third year of the experiments, irrespective of the cultivation method, which may be the result of moisture availability during the whole vegetation season. Multiannual averages did not reveal any significant differences in dry matter content in carrot roots cultivated using different methods.

Table 2

Contents of dry mass and nitrates in carrots depending on cultivation method

Method	Dry mass [% f.m.]				$N-NO_3$ [mg · dm^{-3} juice]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	12.65* n.s.**	13.52 b	11.39 n.s.	12.51 n.s.	158.66 n.s.	155.75 n.s.	144.00 n.s.	152.27 a
Integrated	13.23 n.s.	13.17 b	10.79 n.s.	12.39 n.s.	188.25 n.s.	279.25 n.s.	195.00 n.s.	220.83 b
Organic	12.88 n.s.	11.80 a	11.35 n.s.	12.01 n.s.	127.50 n.s.	188.50 n.s.	60.75 n.s.	125.58 a
Average for year	12.94 b	12.83 b	11.18 a		158.09 n.s.	207.83 n.s.	133.25 n.s.	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

The obtained results are different from the ones reported by Fjelkner-Modig et al [15] who demonstrated higher content of dry mass in organic vegetables in comparison with those from integrated production. Also Rossi et al [16] wrote about increased dry matter in tomatoes from organic cultivation in comparison with conventional one. Nitrate content in carrot roots remained on a low level, constituting between 25.5 and 55.8 % of the norm [11].

Significantly higher nitrate content was registered in the roots from integrated cultivation. The lowest contents were noted in carrot roots grown using organic method but the differences in comparison with the roots from the conventional cultivation are insignificant. The obtained results are not in accordance with the research of Woese et al [7] who demonstrated lower nitrate levels in organic products in comparison with conventional ones.

The contents of the other analyzed chemical components in carrot roots were presented in Table 3.

Soluble sugars content differed depending on the applied method and the year of cultivation. The lowest soluble sugar content was determined in carrot roots cultivated using integrated method, while the highest one in carrot roots from conventional cultivation. Sugar content in organic carrot was comparable with its content in carrots produced by means of traditional method. The year 2008 turned out to be the least favourable for sugar synthesis in carrot roots. On average the greatest quantity of sugar was detected in carrots from 2007. The cause of the obtained results may be sought in the course of thermal and moisture conditions in the analyzed years. Wet and cool summer in 2008 contributed to a limited sugar synthesis in carrot roots.

No differences in ascorbic acid content were noted in carrot yields obtained using different methods. Carrots harvested in 2007 contained apparently higher quantities of this compound. Higher temperatures in June, July and August of the analyzed year in comparison with the analogous months of the other years of the experiment might have been the cause of the changes. Wunderlich et al [17] revealed slightly higher but statistically insignificant content of vitamin C in spring broccoli from organic cultivation as compared with broccoli from the conventional one. Worthington [18], who compared vitamin C contents in various organic vegetables, found its increase between 17 and 52 % in lettuce, spinach, tomato and cabbage in comparison with conventionally grown vegetables, whereas in carrots this vitamin content was by 6 % lower. On the other hand, Rossi et al [16] demonstrated lower content of vitamin C in tomatoes from organic farming as compared with the fruit grown using conventional and integrated method. Also Magkos et al [6] published divergent data in this scope. Mozafar [19] reported that ascorbic acid level was conditioned by nitrogen fertilization and pesticide residue, however various plants responded differently to these factors.

Carotenoid content in carrot roots grown using different methods did not differ significantly. While comparing the composition of tomatoes cultivated using organic, integrated and conventional method, Rossi et al [16] did not notice any differences in β-carotene content in fruit from various cultivations. Leclerc et al [8] reported that β-carotene content in carrots depended on nitrogen dose, irrespectively of the applied

Table 3

Contents of selected components in carrot roots depending on cultivation method

Method	Soluble sugars [% f.m.]				Ascorbic acid [mg %]				Carotenoids [$\mu g \cdot g^{-1}$ f.m.]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	5.80 b*	6.46 b	5.13 ab	5.80 b	6.60 n.s.**	9.00 n.s.	6.27 n.s.	7.35 n.s.	42.79 b	46.32 n.s.	43.65 b	44.3 n.s.
Integrated	5.37 a	5.84 a	4.53 a	5.25 a	6.62 n.s.	9.82 n.s.	5.86 n.s.	7.43 n.s.	36.45 a	57.45 n.s.	38.12 a	44.00 n.s.
Organic	5.73 b	5.55 a	6.04 b	5.77 ab	6.46 n.s.	7.92 n.s.	6.43 n.s.	6.93 n.s.	42.36 b	49.02 n.s.	39.5 a	43.6 n.s.
Average for year	5.62 ab	5.95 b	5.23 a		6.56 a	8.91 b	6.18 a		40.33 a	50.93 b	40.42 a	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

form. Fertilization with big nitrogen doses causes a decline in the level of this compound in plants.

The obtained data show that organic carrot produced the highest root yield which did not differ from carrots grown using conventional method as for the content of sugars or nitrate accumulation level. Carrots produced using integrated method were of the worse quality, since with the yield similar to conventional carrots, they had the least content of soluble sugars in comparison with carrots produced using the other methods.

Conclusions

1. Carrots from conventional cultivation showed significantly lower yield of marketable roots and smaller mass and length of roots. Dry matter content in roots was the highest in comparison with its content in roots from the other cultivations, but differences were not significant. The roots from this cultivation had significantly more sugars as compared with the roots from integrated cultivation.

2. Carrots grown according to the rules of integrated production yielded on the level of plants cultivated using conventional method. They had noticeably greater mass of marketable roots in relation to carrots grown in a traditional way, however no differences in the length of roots coming from both compared cultivations were found. Carrots from integrated production had the highest nitrate content, whereas their sugar content was the lowest as compared with carrots grown using the other methods.

3. Organic method allowed to obtain the highest marketable yield, mass and the length of carrot roots. Nitrates content was the lowest but did not differ significantly from the content in the roots from conventional cultivation. These carrots were characterized by a similar sugar level as carrots cultivated in a conventional way.

4. No significant differences were stated concerning carrot root diameter, dry matter content, ascorbic acid or carotenoids in carrot roots cultivated using various methods.

References

[1] Brat P., George S., Bellamy A. and Du Chauffaut L.: J. Nutr. 2006, **136**, 2368–2373.
[2] Faller A. and Fialho E.: Food Res. Int. 2009, **42**, 210–215.
[3] Manach C., Scalbert A., Morand C., Remesy C. and Jimenez L.: Amer. J. Clinical Nutr. 2004, **79**, 727–747.
[4] Klonsky K.: Agric. Hum. Values 2000, **17**, 233–243.
[5] Lister G.: Hort. Sci. 2006, **41**(2), 296–300.
[6] Magkos F., Arvaniti F. and Zampelas A.: J. Food Sci. Nutr. 2003, **54**(5), 357–371.
[7] Woese K., Lange D., Boess C. and Bogl KW.: J. Sci. Food Agric. 1997, **74**(3), 281–293.
[8] Leclerc J., Miller M.L., Joliot E. and Recquelin G.: Biol. Agric. Hort. 1991, **7**, 349–361.
[9] Rozporządzenie Komisji (EWG) nr 2092/91 z dnia 24 czerwca 1991 r., Dz. Urz.WE L 198 z 22.07.1991 (z późn. zm.).
[10] Yemm E.W. and Wills A.J.: Biochem. J. 1954, **54**, 508–514.
[11] Rozporządzenie Ministra Zdrowia z dnia 13 stycznia 2003 r. w sprawie maksymalnych poziomów zanieczyszczeń chemicznych i biologicznych, które mogą znajdować się w żywności, składnikach żywności, dozwolonych substancjach dodatkowych, substancjach pomagających w przetwarzaniu albo na powierzchni żywności. DzU 2003, nr 37, poz. 326, zał. 2.
[12] Lichtenthaler H.K. and Wellburn A.R.: Biochem. Soc. Trans. 1983, **603**, 591–592.
[13] Samotus B., Leja M. and Ścigalski A.: Acta Agr. Silv., Ser. Agr. 1982, **21**, 105–121.

[14] Krzesiński W. and Knaflewski M.: [in:] Ogólnopolska Konferencja Warzywnicza Postęp w technologii uprawy warzyw korzeniowych, Instytut Warzywnictwa, Skierniewice 2007, p. 50–51.
[15] Fjelkner-Modig S., Bengtsson H., Stegmark R. and Nyström S.: Acta Agric. Scand., Sect B, Soil Plant Sci. 2000, **50**, 102–113.
[16] Rossi F., Godani F., Bertuzzi T., Trevisan M., Ferrari F. and Gatti S.: Eur. J. Nutr. 2008, **47**, 266–272.
[17] Wunderlich S.M., Feldman Ch., Kane S. and Hazhin T.: Int. J. Food Sci. Nutr. 2008, **59**(1), 34–45.
[18] Worthington V.: J. Alternative Complement. Med. 2001, **7**(2), 161–173.
[19] Mozafar A.: J. Plant Nutr. 1993, **16**(12), 2479–2506.

PORÓWNANIE JAKOŚCI MARCHWI UPRAWIANEJ METODAMI KONWENCJONALNĄ, INTEGROWANĄ I EKOLOGICZNĄ

[1] Katedra Przedsiębiorczości i Kształtowania Terenów Zieleni
Wyższa Szkoła Inżynieryjno-Ekonomiczna z siedzibą w Rzeszowie
[2] Katedra Warzywnictwa z Ekonomiką Ogrodnictwa
Uniwersytet Rolniczy w Krakowie

Abstrakt: Doświadczenie prowadzono w latach 2006–2008 z zachowaniem zasad produkcji konwencjonalnej, integrowanej i ekologicznej. Uprawa ekologiczna prowadzona była w gospodarstwie certyfikowanym. Badaniami objęto marchew odmiany 'Flakkee 2'. Na podstawie średnich wyników z trzech lat doświadczeń oceniono wpływ metody uprawy na ilość plonów oraz ich parametry jakościowe, takie jak: średnia masa korzeni handlowych, ich długość i średnica oraz zawartość suchej masy, azotanów, cukrów rozpuszczalnych, kwasu askorbinowego oraz karotenoidów.

Plon ogólny, masa i długość korzeni były największe w uprawie ekologicznej. Zawartość suchej masy marchwi nie różniła się istotnie w korzeniach marchwi pochodzącej z różnych systemów uprawy. Zawartość azotanów w badanych korzeniach była mała i stanowiła 25,5–55,8 % dopuszczalnej normy. Najwięcej azotanów wykryto w korzeniach pochodzących z uprawy integrowanej. Statystycznie istotnie niższy, w stosunku do marchwi z pozostałych upraw, poziom cukrów rozpuszczalnych wykazano w korzeniach marchwi pochodzącej również z tego systemu uprawy. Nie wykazano różnic w zawartości kwasu askorbinowego oraz karotenoidów w korzeniach marchwi pochodzącej z różnych systemów uprawy.

Słowa kluczowe: marchew, uprawa ekologiczna, uprawa integrowana, uprawa konwencjonalna, plonowanie, jakość korzeni

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Wanda WADAS[1]

EFFECT OF MULTINUTRIENT COMPLEX FERTILIZERS ON TOTAL NITROGEN AND NITRATE(V) CONTENT IN THE TUBERS OF VERY EARLY POTATO CULTIVARS

WPŁYW WIELOSKŁADNIKOWYCH NAWOZÓW KOMPLEKSOWYCH NA ZAWARTOŚĆ AZOTU OGÓLNEGO I AZOTANÓW(V) W BULWACH BARDZO WCZESNYCH ODMIAN ZIEMNIAKA

Abstract: The paper presents the results of a three-year study on the effect of an application of the multinutrient complex fertilizers and singlenutrient fertilizers on total nitrogen and nitrate(V) contents in the tubers of very early potato cultivars.

It was found that an application of multinutrient complex fertilizers representing the nitrophoska group, that is Nitrophoska blue special and Viking 13, was followed by an increase in total nitrogen contents in tubers. In turn, an application of HydroComplex was associated with a total nitrogen content which was similar to singlenutrient fertilizers. Polimag S (amophoska group) increased total nitrogen content, compared with singlenutrient fertilizers, only in the year with a higher rainfall over the potato growing season. The present studies demonstrated that a significant increase in nitrate(V) content in tubers followed an application of the multinutrient complex fertilizer HydroComplex which contains most of magnesium and sulphur of all with the nitrophoska group.

Keywords: potato, fertilization, multinutrient complex fertilizers, total N, NO_3-N

Nitrogen compounds, converted to total protein (N × 6.25), account for 1.7 to 2.3 % potato tuber fresh matter. Nitrogen in the form of nitrates represents as little as 0.5 to 1.3 % total nitrogen. However, due to high consumption, potatoes are a source of quite high amounts of these compounds. Approximately 27 % nitrates in a daily diet are potato-derived ones [1, 2]. Accumulation of nitrogen compounds in potato tubers depends on environmental conditions, agronomical factors, cultivar properties and tuber physiological maturity [1, 3–5]. Nitrate concentration in tubers depends, to a large extent, on mineral fertilization. Results of studies indicate that there is a possibility of reducing nitrate contents in tubers due to an application of multinutrient fertilizers [6, 7].

[1] Department of Vegetable Crops, University of Natural Sciences and Humanities in Siedlce, ul. B. Prusa 14, 08–110 Siedlce, Poland, phone: +48 25 643 1296, email: wwadas@uph.edu.pl

The aim of the study was to compare the effect of singlenutrient and multinutrient complex fertilizers on total nitrogen and nitrate(V) content in the tubers of very early potato cultivars.

Materials and methods

The effect of multinutrient complex fertilizers – HydroComplex (12 % N in this 5 % NO_3-N and 7 % NH_4-N, 11 % P_2O_5, 18 % K_2O, 2.6 % MgO, 8 % S, 0.015 % B, 0.02 % Mn, 0.02 % Zn and 0.35 % Fe), Nitrophoska blue special (12 % N in this 5.5 % NO_3-N and 6.5 % NH_4-N, 12 % P_2O_5, 17 % K_2O, 2 % MgO, 6 % S, 0.02 % B and 0.01 % Zn), Polimag S (10 % N in NO_3-N, 8 % P_2O_5, 15 % K_2O, 5 % MgO, 14 % S, 0.1 % B, 0.1 % Cu, 0.2 % Mn and 0.5 % Zn), Viking 13 (13 % N in this 5.3 % NO_3-N and 7.7 % NH_4-N, 13 % P_2O_5, 21 % K_2O, 1.2 % MgO, 4 % CaO and 1.4 % S), and singlenutrient fertilizers (ammonium nitrate, single superphosphate and potassium sulphate) on total nitrogen and nitrate(V) contents in the tubers of very early potato cultivars ('Aster', 'Fresco', 'Gloria') was investigated. The study was carried out in the years 2005–2007 on podzolic soil with a very high content of available phosphorus, mean to very high content of potassium, mean content of magnesium, and pH in 1 mol $\cdot$ dm^{-3} KCl 5.0–6.8. The field experiment was established in the split-plot design with three replications. The multinutrient complex fertilizers and singlenutrient fertilizers were applied in the amounts equivalent to recommended rates for the cultivars tested of 100 kg N $\cdot$ ha^{-1}. The remaining elements in the singlenutrient fertilizers were applied at the rates which guarantee an appropriate N:P:K proportion for edible potatoes, that is 1:1:1.5. Potatoes were harvested at the tuber physiological maturity stage. Laboratory studies were conducted on samples of 50 different-sized tubers taken from each treatment. The content of total nitrogen with Kjeldahl method and nitrate(V) with ionselective nitrate electrode were determined.

Only the growing season of 2007 was characterised by thermal and moisture conditions that were favourable for the cultivation of very early potato cultivars. In 2005 was drought from mid-June to the end of the growing period, and in 2006 was mild drought during the whole growing period.

Results and discussion

The content of total nitrogen in potato tubers ranged from 9.37 to 14.48 g $\cdot$ kg^{-1} d.m.; that of nitrate(V) varied from 66.67 to 94.67 mg $\cdot$ kg^{-1} f.m. Irrespective of the kind of fertilizer applied, most total nitrogen was accumulated by potato tubers in 2006, with the lowest rainfall over the growing season. By contrast, nitrate accumulation in tubers in this year was the lowest (Table 1). High temperature and temporary rainfall shortages during the growing season increase total nitrogen in tubers [1, 8], which was confirmed in the present study.

The singlenutrient fertilizers applied in the experiment did not affect significantly total nitrogen content in tubers (Table 1). An application of the multinutrient complex fertilizers HydroComplex, Nitrophoska blue special and Viking 13 (nitrophoska group) resulted in a similar or higher total nitrogen content in tubers compared with singlenutrient fertilizers. The highest total nitrogen content was determined in the tubers of potato fertilized with Nitrophoska blue special and Viking 13. The respective increases in total nitrogen content amounted to 0.55 and 0.45 g · kg^{-1} d.m. as compared with singlenutrient fertilizers. The highest increase in total nitrogen content as result of fertilization with Nitrophoska blue special and Viking 13 was obtained, respectively, in 2006 with mild drought over the growing season of potato, and in 2007 which was moderately wet. Compared with singlenutrient fertilizers, an application of Polimag S (amophoska group) increased total nitrogen content, on average by 1.44 g · kg^{-1} d.m. only in 2007 with most rainfall in the growing period of potato. By contrast, in the years characterised by rainfall shortages, total nitrogen content in tubers was lower following an application of Polimag S. Studies by other authors demonstrated an increase in nitrogen content in tomato friut as result of fertilization with Polimag S [9].

Table 1

Total N [g · kg^{-1} d.m.] and NO_3-N [mg · kg^{-1} f.m.] content in tubers in relation to the kind of fertilizer and year of cultivation

Kind of fertilizer	N-total				NO_3-N			
	2005	2006	2007	mean	2005	2006	2007	mean
Without fertilizer	10.77	12.66	12.17	11.86	72.56	72.89	81.11	75.52
Singlenutrient fertilizers	11.58	12.75	11.42	11.91	89.00	80.67	79.56	83.07
HydroComplex	10.81	13.19	11.70	11.90	90.78	88.44	82.11	87.11
Nitrophoska blue special	12.06	13,91	11.41	12.46	81.56	76.33	79.67	79.18
Polimag S	10.38	10.92	12.14	11.15	81.56	78.33	82.22	80.70
Viking 13	10.96	13.27	12.86	12.36	84.00	78.00	80.22	80.74
Mean	11.09	12.78	11.95	11.94	83.24	79.11	80.81	80.81
$LSD_{0.05}$:								
Years	0.19				1.88			
kind of fertilizer	0.33				3.29			
years × kind of fertilizer	0.56				5.70			

Nitrate content in plants depends mainly on level of nitrogen fertilization and form of nitrogen. The ammonium and urea forms of nitrogen stimulates the nitrate reductase activity [10, 11]. Compared with cultivation without mineral fertilization, nitrate(V) contents associated with an application of singlenutrient fertilizers and multinutrient complex fertilizers were increased on average by 7.55 mg NO_3 · kg^{-1} f.m., and 3.66 to 11.59 mg NO_3 · kg^{-1} f.m. (Table 1). However, in no cases did it exceed the permissible content of 200 mg NO_3 · kg^{-1} f.m. The smaller was the differences associated with an application of Nitrophoska blue special, Polimag S and Viking 13, than with HydroComplex application. Studies by Jablonski [12] did not show a significant effect of Nitrophoska 12 special on nitrate(V) content in potato tubers. Of the multinutrient complex fertilizers applied, only HydroComplex significantly increased nitrate(V) content compared with singlenutrient fertilizers, the total nitrogen content in tuber dry matter being similar. Following an application of HydroComplex nitrate(V) content was on average by 4.04 mg $NO_3 \cdot kg^{-1}$ f.m higher. Nitrate content in plants depends not only on nitrogen fertilization but also on sustainable fertilization with remaining macro- and microelements [3, 5, 13, 14]. Nitrates accumulate in plants when their uptake is greater than possibility of reduction. Of the multinutrient complex fertilizers with the nitrophoska group applied, HydroComplex contains most of magnesium and sulphur. Increase amount of magnesium in plant fertilization can contribute to increase of nitrate concentration by decrease in nitrate reductase activity [15]. In turn, increase of sulphates decrease in considerable degree uptake of molybdenum by plants, which is component of nitrate reductase [16]. In carrot fertilized with HydroComplex there was observed a reduction in nitrate(V) content. The beneficial influence of HydroComplex on the nitrate content in the carrot roots can be explained by the pace of nitrogen release from this fertilizer, adapted to the nutrition requirements of the plants [17]. Other authors reported that total nitrogen as well as nitrate(V) contents in potato tubers decreased following an application of the fertilizers Kemira solanum and Agro solanum [6, 7].

Table 2

Total N [$g \cdot kg^{-1}$ d.m.] and NO_3-N [$mg \cdot kg^{-1}$ f.m.] content in tubers in relation to the kind of fertilizer and cultivar

Kind of fertilizer	Total N				NO_3-N			
	'Aster'	'Fresco'	'Gloria'	mean	'Aster'	'Fresco'	'Gloria'	mean
Without fertilizer	11.81	12.98	10.81	11.86	77.22	75.67	73.67	75.52
Singlenutrient fertilizers	10.94	13.23	11.57	11.91	84.89	80.22	84.11	83.07
HydroComplex	12.06	12.62	11.02	11.90	86.11	85.67	89.56	87.11
Nitrophoska blue special	12.13	13.25	11.99	12.46	78.78	80.56	78.22	79.18
Polimag S	10.82	11.40	11.23	11.15	77.78	87.33	77.00	80.70
Viking 13	11.67	12.56	12.86	12.36	79.00	83.22	80.00	80.74
Mean	11.57	12.67	11.58	11.94	80.63	82.11	80.42	81.06
$LSD_{0.05}$:								
kind of fertilizer	0.33				3.29			
cultivar	0.16				1.57			
kind of fertilizer × cultivar	0.47				4.70			

Regardless of the kind of fertilizer applied, tubers of 'Fresco' cv. contained more total nitrogen compounds and nitrates(V) than 'Aster' and 'Gloria' cvs. (Table 2). Total nitrogen content and nitrate(V) content in the tubers of 'Fresco' cv. were on average, respectively, by 1.10 $g \cdot kg^{-1}$ d.m. and 1.58 mg $NO_3 \cdot kg^{-1}$ f.m. higher. The cultivars examined displayed a varied response to fertilizers applied. An application of Nitrophoska blue special and Viking 13 was followed by the highest increase in total nitrogen content in the tubers of, respectively, 'Aster' and 'Gloria' cvs. A higher increase in nitrate(V) content following an application of HydroComplex was recorded for tubers of 'Fresco' and 'Gloria' compared with 'Aster' cv.

Conclusions

1. Rainfall shortages over the potato growing season increased total nitrogen compound contents in tubers, which was accompanied by a considerable decreas in nitrate(V) concentration.

2. When the multinutrient complex fertilizers (nitrophoska group) Nitrophoska blue special and Viking 13 were applied, total nitrogen content in tubers was higher, and an application of HydroComplex resulted in similar total nitrogen contents compared with singlenutrient fertilizers.

3. An application of Polimag S (amophoska group) increased total nitrogen content compared with singlenutrient fertilizers only in the year with higher rainfall over the potato growing season.

4. Nitrate(V) contents in tubers increased only when the multinutrient complex fertilizer HydroComplex containing most of magnesium and sulphur of all with the nitrophoska group was applied.

5. Regardless of the kind of fertilizer applied, tubers of 'Fresco' cv. contained more total nitrogen and nitrates(V) than 'Aster' and 'Gloria' cvs.

References

[1] Roztropowicz S.: Fragm. Agronom. 1989, **1**, 33–75.
[2] Stasiak A. and Wilska-Jeszka J.: Przem. Ferm. Owoc.-Warzyw. 1983, **5**, 17–21.
[3] Cieślik E.: Post. Nauk Roln. 1995, **6**, 67–73.
[4] Frydecka-Mazurczyk A. and Zgórska K.: Żywność 2000, **4**(25) SUPL., 46–52.
[5] Rogozińska I., Pawelzik E., Pobereżny J. and Delgado E.: Potato Res. 2005, **48**, 167–180.
[6] Bernat E. and Jabłoński K.: Folia Univ. Agric. Stetin. 190, Agricultura 1998, **72**, 21–27.
[7] Jabłoński K.: Folia Univ. Agric. Stetin. 223, Agricultura 2001, **89**, 81–86.
[8] Lachman J., Hamouz K., Dvořák P. and Orsák M.: Plant Soil Environ. 2005, **51**(10), 431–438.
[9] Mazur Z. and Tomaszewska Z.: Zesz. Probl. Post. Nauk Roln. 2006, **513**, 259–263.
[10] Sady W., Wojciechowska R. and Rożek S.: Acta Hort. 2001, **563**, 123–128.
[11] Serio F., Elia A., Signore A. and Santamaria P.: J. Sci. Food Agric. 2004, **84**(11), 1428–1432.
[12] Jabłoński K.: Zesz. Probl. Post. Nauk Roln. 2006, **511**, 309–315.
[13] Hlusek J., Hrivna L. and Svaboda J.: Ecol. Chem. Eng. 2002, **9**(11), 1373–1382.
[14] Rożek S.: Zesz. Nauk. AR Kraków 364, Sesja Nauk. 2000, **71**, 19–31.
[15] Buczek J.: Acta Physiol. Plant. 1980, **2**(3), 222–232.
[16] Mokrzecka E.: Roczn. Nauk Roln., ser. A 1990, **108**, 173–179.
[17] Sady W. and Rożek S.: Veget. Crops Res. Bull. 2002, **54**, 55–59.

WPŁYW WIELOSKŁADNIKOWYCH NAWOZÓW KOMPLEKSOWYCH NA ZAWARTOŚĆ AZOTU OGÓLNEGO I AZOTANÓW(V) W BULWACH BARDZO WCZESNYCH ODMIAN ZIEMNIAKA

Katedra Warzywnictwa
Uniwersytet Przyrodniczo-Humanistyczny w Siedlcach

Abstrakt: Porównywano wpływ wieloskładnikowych nawozów kompleksowych i nawozów jednoskładnikowych na zawartość azotu ogólnego i azotanów(V) w bulwach bardzo wczesnych odmian ziemniaka.

Po zastosowaniu wieloskładnikowych nawozów kompleksowych z grupy nitrofosek: Nitrophoska special niebieska i Viking 13, ogólna zawartość azotu w bulwach była większa, a po zastosowaniu HydroComplexu podobna jak przy stosowaniu nawozów jednoskładnikowych. Stosowanie nawozu Polimag S, z grupy amofosek, tylko w roku z większą ilością opadów w okresie wegetacji ziemniaka powodowało zwiększenie ogólnej zawartości azotu w porównaniu z nawozami jednoskładnikowymi. Badania wykazały istotny wzrost zawartości azotanów(V) w bulwach tylko po zastosowaniu wieloskładnikowego nawozu kompleksowego HydroComplex, zawierającego najwięcej magnezu i siarki ze wszystkich stosowanych nitrofosek.

Słowa kluczowe: ziemniak, nawożenie, wieloskładnikowe nawozy kompleksowe, N ogólny, $N\text{-}NO_3$

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Dorota WALKOWIAK-TOMCZAK[1],
Róża BIEGAŃSKA-MARECIK[1]
and Elżbieta RADZIEJEWSKA-KUBZDELA[1]

CHANGES IN CONTENTS OF NITRATES(V) AND NITRATES(III) IN SMALL RADISH PACKAGED AND STORED IN MODIFIED ATMOSPHERE

ZMIANY ZAWARTOŚCI AZOTANÓW(V) I AZOTANÓW(III) W RZODKIEWCE ZAPAKOWANEJ I PRZECHOWYWANEJ W ATMOSFERZE MODYFIKOWANEJ

Abstract: The aim of the study was to analyze changes in contents of nitrates(V) and nitrates(III) in small radish packaged in modified atmosphere using film with different oxygen permeability (3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ and 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$). In the packaging process air atmosphere was applied as well as modified atmosphere with the two following composition: 10 % O_2, 10 % CO_2, 80 % N_2 and 20 % O_2, 25 % CO_2, 55 % N_2. Samples were stored for 12 days at 4 C.

In fresh small radish nitrate(V) content was 1608 $mg \cdot kg^{-1}$. During storage of analyzed samples a statistically significant ($p \le 0.05$) increase was observed in the contents of the above-mentioned compounds, irrespective of the applied atmosphere composition and the type of packaging film. The presence of nitrates(III) was detected only after 12 days of storage in small radish packaged in modified atmosphere using film with oxygen permeability of 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$. It results from conducted analyses that the application of film with high oxygen permeability in the packaging of small radish, both in case of air atmosphere and atmosphere with the percentage composition of $O_2/CO_2/N_2$: 10/10/80 and 20/25/55, makes it possible to maintain aerobic conditions inside the packaging and thus prevent the accumulation of nitrates(III).

Keywords: small radish, nitrates(V) and nitrates(III), modified atmosphere, films with different oxygen permeability

Vegetables are valuable sources of vitamins, minerals and bioactive compounds in human diet, but at the same time they may contain substances harmful for the human organism, such as nitrates(V) and nitrates(III) as well as heavy metals, which they absorb from the soil and atmosphere. Nitrates(V) are accumulated first of all in root vegetables, vegetables with a short vegetation period as well as early vegetable cultivars

[1] Institute of Food Technology of Plant Origin, Poznan University of Life Sciences, ul. Wojska Polskiego 28, 60–637 Poznań, Poland, phone: +48 61 846 6043, email: tomczak@up.poznan.pl

[1]. One needs to focus here on greenhouse-grown vegetables, which due to the intensive nitrate(V) fertilization, insufficient lighting and limited vegetation period, are to a considerable degree at risk of nitrate(V) accumulation [2]. The accumulation of nitrates(V) in plants is affected by botanic factors, such as species, cultivar or maturation stage, and environmental factors, eg nitrogen rate and date of fertilizer application, temperature, insolation, mineral resources and moisture content of soil [3]. The adopted methods of transport and storage after harvest also have an effect on the metabolism of nitrates(V) and nitrates(III) in vegetables.

Small radish as a vegetable with a very short vegetation period, accumulating reserve substances in the thickening of the stem section below the cotyledon, frequently grown in greenhouses for early spring harvest, tends to accumulate nitrates(V), which may next be reduced to nitrates(III). Literature data confirm that the activity of nitrate(V) reductase is connected with the availability of sugars and light. Thus insufficient lighting in case of greenhouse or early spring growing creates conditions reducing the course of photosynthesis (formation of carbohydrates) and inhibiting the activity of nitrate(V) reductase responsible for nitrate metabolism [4]. In case of small radish excess nitrates(V) in the stem thickening result not only from intensive fertilization, but also conditions and duration of transport and storage, as well as those under which the vegetable is stored by consumers at home, which frequently leads to wilting and scalding of vegetables. Plants with yellow, rotting leaves constitute a potential source of harmful nitrates(III) and N-nitroso compounds [5].

Modified atmosphere packaging is a method used with increasing frequency to extend the shelf life and storage time for minimally processed vegetables. However, the composition of atmosphere inside the packaging, changing during vegetable storage, may contribute to a considerable deterioration of raw material quality or even pose a health hazard. Thus the application of a packaging material adequately selected to suit a given raw material is a significant element determining the quality of the stored product, including also a limitation of nitrate(III) accumulation and the application of biologically active compounds.

The aim of the study was to investigate changes in contents of nitrates(V) and nitrates(III) as well as physicochemical characteristics and sensory attributes of small radish packaged in modified atmosphere, using film with different oxygen permeability.

Materials and methods

The analyses were conducted on greenhouse-grown small radish, harvested in February and purchased in a retail outlet.

Tested raw material was washed, inedible parts were removed and then it was again washed and dried. Next radish was packaged in batches of 100 g into 15 × 21 cm plastic bags of elastic film with oxygen permeability of 3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ (My Films Standard, Cryovac, Polska) and 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ (PA/PE 75 MY, Multivac, Polska). Bags were sealed in air atmosphere and in modified atmosphere with the two following compositions: 10 % O_2, 10 % CO_2, 80 % N_2 and 20 % O_2, 25 % CO_2, 55 % N_2 (an A 300 Multivac sealing machine). The product was stored for 12 days at 4 ^oC.

Analyses of nitrate(V) and nitrate(III) contents, sensory examination as well as measurements of active acidity, soluble solids contents and changes in O_2 and CO_2 contents in the atmosphere inside the packaging were conducted after 1, 6 and 12 days of storage.

Contents of nitrates(V) and nitrates(III) were determined by colorimetry using Griess reagents (wavelength λ = 538 nm), with the use of direct reduction of nitrates(V) to nitrates(III) by metallic cadmium, in accordance with Polish Standard PN-92/A-75112, being an equivalent of ISO 6635:1984 [6]. In the preliminary stage of determination samples were shaken with active carbon in order to remove the colouring originating from chlorophyll.

Sensory examination was performed immediately after the opening of bags with radishes. Examinations were conducted using a 5-point scale, in three replications for each sample. Contents of oxygen and carbon dioxide in the atmosphere inside the packaging were determined in three replications using an OXYBABY®V wireless gas analyzer by Witt-Gasetechnik. Soluble solids contents were determined according to Polish Standard PN-90/A 75101/02 [7], while active acidity – according to PN-90/A 75101/06 [8].

Statistical analysis of results was conducted based on the univariate analysis of variance and LSD Fisher's test. Statistically significant differences were described at the significance level $p \le 0.05$. The analysis was performed using Statistica ver. 7.0 software (StatSoft, Poland).

Results and discussion

In the raw material the content of nitrates(V) was 1608 mg $NaNO_3 \cdot kg^{-1}$ d.m., while nitrates(III) were not detected. Nitrate(V) content in samples after 1-day storage was similar to their level in the raw material, ranging from 1352 to 1884 mg $\cdot$ kg^{-1} d.m. (Fig. 1). In the course of storage of analyzed samples, a statistically significant ($p \le 0.05$) increase was recorded in the contents of the above-mentioned compounds, irrespective of the applied composition of atmosphere and the type of packaging film. The increase in the contents of nitrates(V) in analyzed samples ranged from approx. 8 % in samples packaged in film with oxygen permeability of 3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ to approx. 25 % in samples packaged in film with permeability of 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$. Such an increase in the level of nitrates in plant origin materials may result from physiological changes in nitrogen compounds [9]. The contents of analyzed compounds in all samples were no more than 2000 mg $\cdot$ kg^{-1}.

Admissible daily intake of nitrates(V), according to FAO/WHO [10], is 350 mg $NaNO_3 \cdot day^{-1}$ (for an individual weighing 70 kg). In case of fresh radish a portion of approx. 220 g covers ADI (*Acceptable Daily Intake*, mg/kg)) for an individual weighing 70 kg, while in case of stored small radishes the admissible daily intake of nitrates(V) would be supplied in a portion of approx. 170 g. The above examples concern adults, while in case of children the consumption of several radishes

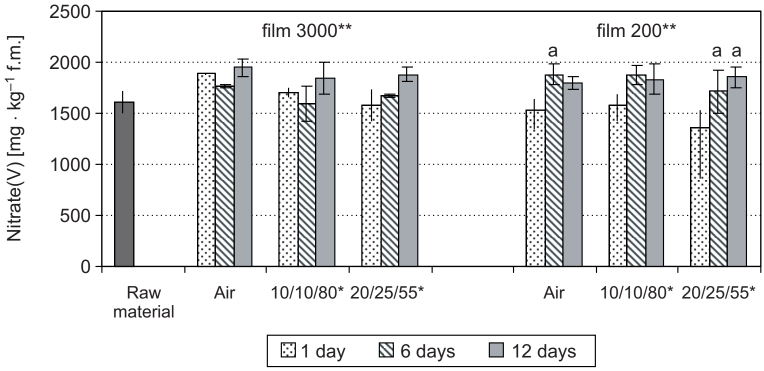

Fig. 1. Changes in nitrates(V) contents in stored small radish packaged in modified atmosphere using film with different oxygen permeability: * – composition of modified atmosphere $\%O_2/\%CO_2/\%N$; ** – film with oxygen permeability in $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$; a – statistically significant differences ($p \leq 0.05$) between: the contents nitrates(V) after 6, 12 days of storage and after 1 day storage (within the same variant)

would result in exceeded ADI for nitrates(V). Thus it is advisable to suggest a reduced consumption of large amounts of small radishes, especially in the autumn and winter period. In that time this vegetable comes from greenhouse cultivation, with intensive fertilization and poor lighting under short day conditions. This results in the reduction of photosynthesis and the accumulation of nitrates(V) absorbed from the substrate [5]. Light is the primary factor regulating the activity of nitrate(V) and nitrate(III) reductases, contributing to the assimilation of reduced forms of nitrogen [11, 12].

After 12-day storage in radish packaged in modified atmosphere in film with oxygen permeability of 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ the presence of nitrates(III) was detected (Fig. 2). In these bags anaerobic conditions were generated as early as after 6 days of storage. In contrast, in analogous samples packaged in film with oxygen permeability of 3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$, nitrates(III) were not detected and the concentration of

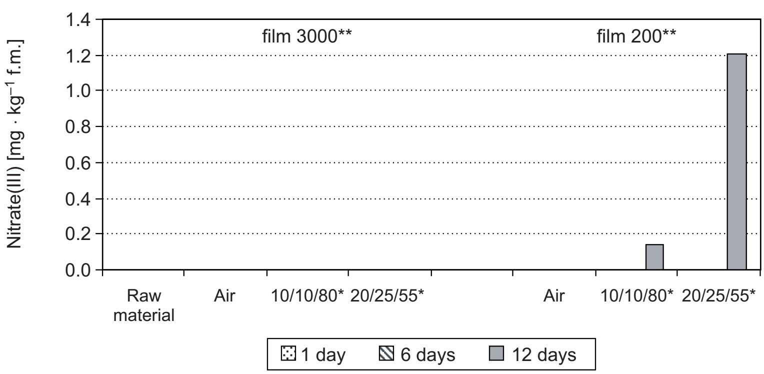

Fig. 2. Changes in nitrates(III) contents in stored small radish packaged in modified atmosphere using film with different oxygen permeability (explanations as in Fig. 1)

oxygen in the packagings was at least 10 %. Thus it may be concluded that the application of packagings with high oxygen permeability during storage of radishes in air or modified atmosphere with the two following compositions: 10 % O_2/10 % CO_2/80 % N_2 and 20 % O_2/25 % CO_2/55 % N_2, prevents the generation of anaerobic conditions in the packaging, which would be conducive of the accumulation of nitrates(III) in the stored product. Bakowski et al [13] recorded an increase in the contents of nitrates(III) to approx. 100 mg $\cdot$ kg^{-1} in spinach packaged in impermeable plastic bags as early as after 4 days of storage.

Radish, as a vegetable of the turnip family, is characterized by high respiration intensity, ie 40–70 mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$ [14]. This raw material after harvest wilts fast and becomes scalded, which makes it suitable only for immediate consumption [15]. However, small radishes are available both in wholesale and retail sold on trays and sealed with solid film, which – as it results from the analyses presented above – may constitute a health hazard at their considerable consumption.

Based on the conducted measurements of gas contents in the atmosphere inside the packaging with stored radish it was found that in samples packaged in film with low oxygen permeability (200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$) anaerobic conditions are generated as early as after 6-day storage and at the same time high contents of carbon dioxide were recorded (from 25 to 40 %). In these samples, as it was described above, the presence of nitrates(III) and a higher increase in the contents of nitrates(V) were found. It results from literature data that the application of too high concentration of carbon dioxide in the atmosphere inside the packaging may cause in case of vegetables physiological changes and microbiological spoilage [16]. Sensitivity to high carbon dioxide concentrations is dependent on the species of the raw material, the degree of its comminution and storage temperature. In most studies concerning modified atmosphere packaging of vegetables a 20–30 % concentration of carbon dioxide is reported to be the threshold level, not causing physiological damage to packaged products [17–19]. In case of radish there is no available literature data defining the threshold concentration of carbon dioxide in the atmosphere, which would not cause any physiological changes.

Adverse changes caused by a high proportion of carbon dioxide in the atmosphere inside the packaging with stored radish were confirmed by sensory examination. Samples in which anaerobic conditions were formed after 12-day storage received the lowest scores in the overall sensory examination (2.6, 2.3, 2.1) (Table 1).

In samples packaged in film with high oxygen permeability (3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$), both in air and modified atmosphere, the presence of oxygen was recorded throughout their entire storage, at the simultaneous low levels of carbon dioxide in the packaging. These samples also received high scores in sensory examination throughout their storage, from 4.7 to 5.0 (Table 1).

Values of pH in analyzed products after 1-day storage ranged from 6.3 to 6.4. During storage a significant decrease in pH of samples was recorded and after 12-day storage these values ranged from 6.1 to 6.3 (Table 1). A similar dependence was reported in case of soluble solids contents in the analyzed product, which decreased significantly

Table 1

Changes of sensory and physicochemical properties and contents of oxygen and carbon dioxide in the atmosphere inside the package with small radish packaged in modified atmosphere, using film with different oxygen permeability

Composition of the atmosphere in package	Oxygen permeability of packaging fim	Time of storage	Parametr evaluated				
			Contents of CO_2 in atmosphere inside the package	Contents of O_2 in atmosphere inside the package	Overall sensory examinations	pH	Soluble solids
	[$cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$]	[days]	[%]		[-]	[-]	[%]
Raw material			—	—	5.0	6.1	2.4
Air	3000	1	2.3	16.0	5.0	6.3	2.3
	3000	6	3.5	11.5 a	5.0	6.2	2.5 a
	3000	12	3.0	16.0	5.0	6.1	2.1
10 % O_2/10 % CO_2/ 80 % N_2	3000	1	4.6 b	12.1 b	5.0	6.3	2.1
	3000	6	3.4	14.4 ab	4.7 ab	6.2	2.5 a
	3000	12	2.2 a	18.7 ab	5.0	6.1	2.2
20 % O_2/25 % CO_2/ 55 % N_2	3000	1	3.9	18.9 b	5.0	6.3	2.2
	3000	6	1.8 a	18.7 b	4.9 a	6.2 a	2.5 a
	3000	12	1.2 a	20.2 b	5.0	6.1 a	2.1

Table 1 contd.

Composition of the atmosphere in package	Oxygen permeability of packaging fim	Time of storage	Parametr evaluated				
			Contents of CO_2 in atmosphere inside the package	Contents of O_2 in atmosphere inside the package	Overall sensory examinations	pH	Soluble solids
	[$cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$]	[days]	[%]		[-]	[-]	[%]
Raw material			—	—	5.0	6.1	2.4
Air	200	1	3.8	13.3 c	5.0	6.4	2.3
		6	13.7 ac	0.0 ac	4.9	6.4 c	2.4
		12	24.5 ac	0.0 ac	2.6 ac	6.3 c	2.1 a
10 % O_2/10 % CO_2/ 80 % N_2		1	8.9 bc	4.8 bc	5.0	6.3	2.3
		6	17.0 abc	0.0 ac	4.4 abc	6.4 c	2.5 a
		12	21.2 abc	0.0 ac	2.3 abc	6.4 c	2.1 a
20 % O_2/25 % CO_2/ 55 % N_2		1	18.9 abc	16.4 bc	5.0	6.4	2.3
		6	29.5 abc	0.0 ac	3.9 abc	6.4 c	2.5 a
		12	39.4 abc	0.0 ac	2.1 abc	6.3 c	2.1 a

a – statistically significant differences ($p \leq 0.05$) between: the value of researches parameter after 6, 12 days of storage and after 1 day storage (within the same variant); b – statistically significant differences ($p \leq 0.05$) between: the value of researches parameter of samples packaged in modified atmosphere and samples packaged in air, after the same storage time; c – statistically significant differences ($p \leq 0.05$) between: the value of researches parameter of samples packaged in film with oxygen permeability 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ and samples packaged in film with oxygen permeability 3000 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$, after the same storage time.

after 12-day storage in all samples, irrespective of the packaging material and the composition of atmosphere applied in packaging.

Conclusions

1. Contents of nitrates(V) in the raw material and in samples after 1-day storage ranged from 1352 to 1884 mg $\cdot$ kg^{-1} d.m.

2. In small radish packaged in modified atmosphere using film with oxygen permeability of 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ the presence of nitrates(III) was detected after 12-day storage.

3. In samples packaged in film with oxygen permeability of 200 $cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ after 6-day storage in anaerobic atmosphere was generated with high contents of carbon dioxide. These samples also received the lowest scores in the overall sensory examination.

4. It results from the conducted analyses that the application of film with high oxygen permeability to package small radish, both in air and modified atmosphere with the percentage composition of $O_2/CO_2/N_2$: 10/10/80 and 20/25/55, makes it possible to maintain aerobic conditions inside the packaging and thus prevent the accumulation of nitrates(III).

References

[1] Grevsen K. and Kaack K.: J. Veget. Crop. Product. 1996, **2**, 15–19.

[2] Tyksiński W., Kozik E. and Bosiacki M.: Acta Agrophys. 2006, **7**(3), 733–740.

[3] Ximenes M.I.N., Rath S. and Reyes F.G.R.: Talanta 2000, **51**, 49–56.

[4] Lillo C.: Physiol. Plant. 1994, **90**, 616–620.

[5] Stępowska A.: Hasło Ogrodnicze 2000, **9**, 50–51.

[6] PN-92/A-75112. Owoce, warzywa i ich przetwory. Oznaczanie zawartości azotynów i azotanów.

[7] PN-90/A-75101/02. Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizyko-chemicznych. Oznaczanie zawartości ekstraktu ogólnego.

[8] PN-90/A-75101/06. Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizyko-chemicznych. Oznaczanie kwasowości ogólnej.

[9] Jaworska G. and Kmiecik W.: EJPAU, Food Sci. Technol. 1999, **2**, 1–10.

[10] JECFA: Joint FAO/WHO Expert Committee on Food Additives – Evaluation of certain food additives and contaminants. World Health Organization, 2002.

[11] Dapoigny L., de Tourdonnet S., Roger-Estrade J., Jeuffroy M.H. and Fleury A.: Agronomie 2000, **20**, 843–855.

[12] Rożek S. and Wojciechowska R.: Folia Hort. 1990, **12**, 53–64.

[13] Michalik H. and Bąkowski J.: Przem. Ferm. i Owoc. Warzyw. 1996, **6**, 32–34.

[14] Robertson G.C.: Food Packaging: principles and practice. CRC Press Book, New York, 2006, p. 361–386.

[15] Grzesiuk S. and Górecki R.: Fizjologia plonów. Wprowadzenie do przechowalnictwa. Wyd. Akademii Rolniczo-Technicznej, Olsztyn 1994, p. 33–76.

[16] Carlin F., Nguyen-The C., Chambroy Y. and Reich M.: Int. J. Sci. Technol. 1990, **25**, 110–119.

[17] Kader A.A., Zagory D. and Karbel E.L.: CRC Crit. Rev. Food Sci. Nutr. 1989, **28**, 1–30.

[18] Sonneveld K.: Packaging Technol. Sci. 2000, **13**, 29–35.

[19] Fonseca S.C., Oliveira F.A.R. and Brecht J.K.: J. Food Eng. 2002, **52**, 99–119.

ZMIANY ZAWARTOŚCI AZOTANÓW(V) I AZOTANÓW(III) W RZODKIEWCE ZAPAKOWANEJ I PRZECHOWYWANEJ W ATMOSFERZE MODYFIKOWANEJ

Instytut Technologii Żywności Pochodzenia Roślinnego
Uniwersytet Przyrodniczy w Poznaniu

Abstrakt: Celem pracy było zbadanie zmian zawartości azotanów(V) i (III) w rzodkiewce zapakowanej w atmosferze modyfikowanej, z zastosowaniem folii o różnej przepuszczalności tlenu ($3000\ cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$ oraz $200\ cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$). Do pakowania zastosowano atmosferę powietrza oraz atmosferę modyfikowaną o następującym dwóch wariantach składu: 10 % O_2, 10 % CO_2, 80 % N_2 oraz 20 % O_2, 25 % CO_2, 55 % N_2. Próbki przechowywano przez 12 dni w temperaturze 4 °C.

W świeżej rzodkiewce zawartość azotanów(V) wynosiła $1608\ mg \cdot kg^{-1}$. W czasie przechowywania badanych próbek, odnotowano istotny statystycznie ($p \le 0.05$) wzrost zawartości azotanów(V), niezależnie od zastosowanego składu atmosfery oraz rodzaju folii opakowaniowej. Obecność azotanów(III) stwierdzono jedynie po 12 dniach przechowywania, w rzodkiewce zapakowanej w atmosferze modyfikowanej przy zastosowaniu folii o przepuszczalności tlenu $200\ cm^3 \cdot m^{-2} \cdot 24\ h^{-1} \cdot bar^{-1}$. Z przeprowadzonych badań wynika, że zastosowanie do pakowania rzodkiewki folii o dużej przepuszczalności tlenu zarówno przy zapakowaniu jej w atmosferze powietrza, jak i w atmosferze o procentowym udziale $O_2/CO_2/N_2$: 10/10/80 i 20/25/55 pozwala zachować warunki tlenowe wewnątrz opakowania, a tym samym uniknąć kumulacji azotanów(III).

Słowa kluczowe: rzodkiewka, azotany(V) i (III), atmosfera modyfikowana, folie o różnej przepuszczalności dla tlenu

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Renata WOJCIECHOWSKA[1*] and Piotr SIWEK[1]

EFFECT OF FILM USED IN LOW TUNNELS AND FOR PLANT SHADING ON NITRATE METABOLISM IN CELERY STALKS

WPŁYW FOLII STOSOWANEJ W TUNELACH NISKICH ORAZ DO CIENIOWANIA NA METABOLIZM AZOTANÓW W OGONKACH LIŚCIOWYCH SELERA NACIOWEGO

Abstract: The results of three-year studies (2005–2007) on the effect of various colours of film (transparent, white, and black) made of original and recycled materials used as tunnel covers and plant shades before harvest on the nitrate metabolism in celery, 'Tango' cv., have been presented. Nitrate content, nitrate reductase activity as well as ammonium ions and free amino acid content in celery stalks were estimated. In the first experiment celery plants were grown in tunnels since the day of planting, then the films were removed a month before harvest and in the second one – film shades of proper films were fixed on the low tunnels construction two weeks before harvest.

The content of nitrate and its metabolism was more significantly modified in the second experiment; with the reducing PAR permeability of film, the significant decrease of nitrate activity in celery stalks was shown. In both experiments the lowest content of nitrates was estimated in stalks of the celery grown under transparent film. The highest content of free amino acids in celery stalks in black film application was observed. The film colour had greater effect on nitrate content and its metabolism than the material of the film.

Keywords: transparent, white and black film, nitrates, nitrate reductase, ammonium ions

The quantity and quality of the celery yield is commonly modified by the field cultivation factors, for example by mulching [1] and direct stalks shading [2]. Some studies showed that plant shading can effectively improve the commercial value of cucumber fruits and celery stalks in respect to their appearance and taste [3]. However, reducing access to light can modify many physiological processes in plants, particularly photosynthesis and nitrogen metabolism. For example, light is a necessary factor to

[1] Department of Botany and Plant Physiology, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, Poland, phone: +48 12 662 52 08, email: rwojciechowska@ogr.ur.krakow.pl

[2] Department of Vegetable Crops, Faculty of Horticulture, University of Agriculture in Krakow, al. 29 Listopada 54, 31–425 Kraków, phone: +48 12 662 52 17, Poland, email: psiwek@ogr.ur.krakow.pl

nitrate reduction [4]. Lower light intensity which usually occurs under shades, may result in decrease of nitrate reductase activity, the enzyme responsible for nitrate level in plants [5].

Nitrate(V) is a natural and important component of vegetable, which play nutritional and signaling role affecting the proper growth and development of plants. According to the recent scientific opinion [6], there is a sustained need for research on factors that influence nitrate content in edible parts of vegetables. Because of the risk to human health from nitrates(III) and N-nitroso compounds, which appear during incomplete reduction of nitrates after vegetable consumption, such studies are very important. Some works indicate that leafy vegetables, including celery plants may accumulate considerable amounts of nitrates [7]. However, in available literature there are only a few studies on the effect of plant direct shading on nitrate content and their metabolism in vegetables.

The main objective of this study was to determine the effect of transparent, white and black films made of original and recycled materials, used in low tunnels and plant shades before harvest on nitrate reductase activity and nitrate and ammonium ions content in stalks of celery 'Tango' cv.

Material and methods

The study with celery (*Apium graveolens* L. var. *dulce*) 'Tango' cultivar was carried out in 2005–2007 at Experimental Station University of Agriculture in Krakow. Each year in the autumn field was fertilized with phosphorous and potassium in dose of 100 kg $P_2O_5 \cdot ha^{-1}$ and 200 kg $K_2O \cdot ha^{-1}$ and with manure (35 $Mg \cdot ha^{-1}$). In the spring 2005–2007 prior to planting, the field was fertilized with 50, 75 and 50 kg $N \cdot ha^{-1}$ (NH_4NO_3 + $CaCO_3$), respectively, and after planting each year with 20 kg $N \cdot ha^{-1}$ (NH_4NO_3). Celery seedlings were planted in 30 × 25 cm distance on 20, 19 and 17 April and collected on 7–8, 12–13 and 4–5 July, respectively.

The work concerns two experiments. In the first, celery plants were grown in low tunnels (1.5 m width, 0.75 m height and 10 m length) since planting to 30th May 2005, 1st June 2006, and 2nd June 2007. In the second – plants were shaded for 14 days before harvest. In both experiments various kinds of plastic films were used: transparent, white and black made of original and recycled material. Seventh treatment was control (plants without film). All polyethylene films of original (Basell Orlen Polyolefins) and recycled (Gumiplast) material were manufactured by "Jagapol" Film Manufacturing Facility in Krakow. The higher PAR (*Photosynthetically Active Radiation*) transmission was determined for transparent films – original (87.1 %) and recycled (83.7 %) used for the covering of tunnels, followed by white (60 and 63 %, respectively) and black (33.8 and 38.6 %) films. The lower transmission had white and black films used for shading before harvest [8].

Each treatment consisted of 160 plants (four fields of 3 m^2 area with 40 plants). On the day of harvest, about 9 a.m., 12 plants (3 from each treatment) were randomly collected for chemical analyses. From each plant a representative leaf of the middle part of celery rosette (not outer and not inner) has been selected. *Nitrate reductase* activity

(NR) was determined in accordance with Jaworski method slightly modified by Rozek [9]. NO_3^- and NH_4^+ ions content in plant extracts (prepared in 0.02 mol · dm^{-3} $Al_2(SO_4)_3 \cdot 18\ H_2O$) was determined using ion-selective electrodes connected to ORION 920A + ionometer. The total free amino acids were estimated according to Korenman [10].

The results were statistically analysed using Neumann-Keuls test at a significant level of $p = 0.05$.

Results and discussion

In the first experiment (Table 1) both nitrate reductase activity and nitrate ions content in celery stalks were distinctly differentiated. These results might have been associated with climatic factors which differed in each year of the study [11]. Higher accumulation of nitrates in 2006 was accompanied by lower NR activity in comparison with other years. Low rainfalls and high air temperature in May and June 2006 might have been the reason for inhibition of nitrate reductase, which results in higher nitrate accumulation in plants, especially noticable in stalks from black film treatments. It has been shown, that drought [12] and deficit of light [4] are factors strongly inhibiting the activity of nitrate reductase in leaves. In 2007 better weather conditions [11] affected the decreasing of nitrate level and increasing of ammonium ions, the final product of nitrate reduction. The amino acids level was in general less differentiated in individual years of experiment, slightly higher in stalks with more intense nitrate metabolism.

It seems to be possible that in the first experiment nitrate metabolism in celery stalks was slightly modified by the kind of plastic film used for tunnels covering. In May/June, after stabilizing of temperature conditions films were removed from the tunnel constructions. Presented results (Table 1) were reflection of two factors: the shading in April/May and the weather conditions in the final stage (June) of celery growing period. However, it is interesting, that in each year of the study the lowest values of nitrates content (in comparison with control plants, too) were in celery stalks from tunnels covered with transparent film and in 2007 additionally with the white one. This observation suggests the positive effect of transparent film used as low tunnel covers for covering of low tunnels in the first stage of vegetation to improve the celery stalks quality. Despite of the lowest content of nitrates, the highest level of ascorbic acid and soluble sugars in this case was shown [11].

The nitrate metabolism was more distinctly modified in the second experiment when films of various colour and material were fixed on the low tunnels construction in the middle of June, two weeks before harvest (Table 2). The obtained results are connected with differences in physical properties of films. In general, with the reducing film transmission for light, the decrease of nitrate reductase activity and increase of nitrates in celery stalks was shown. Comparable results were obtained in the similar study with butterhead lettuce ,'Melodion' cv. [13]. Rapid plant shading influences a significant decrease of nitrate reductase activity by phosphorylation Ser residue of the enzyme. Light induces dephosphorylation and thereby activation of NR. Moreover, light

Table 1

The effect of kind of plastic film used for covering of low tunnels on nitrate(III) reductase activity (NR, µmol NO_2^- · g^{-1} f.m. · h^{-1}), nitrate(V) ions (µmol NO_3^- · g^{-1} f.m.), ammonium ions (µmol NH_4^+ · g^{-1} f.m.) and free amino acids (mg N · 100 g^{-1} f.m.) content in celery stalks in 2005–2007

Kind of plastic film	Nitrate reductase activity			Nitrate ions			Ammonium ions			Free amino acids		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Control	19.09 aA	5.11 aA	77.39aB	12.14eD	8.22 cB	4.26 dC	25.76bB	21.38eC	43.51 bB	5.89 cB	5.88 dD	7.84 dD
Transparent original	17.04 a	8.66 b	58.28 a	2.56 a	1.91 a	0.95 a	25.76 b	17.56 b	41.89 b	5.54 b	4.01 b	6.49 b
Transparent recycled	18.29 a	10.04 b	57.18 a	2.22 a	2.69 b	0.90 a	26.14 b	16.18 a	44.38 b	4.88 a	3.68 a	5.91 a
Mean for transparent	17.67 A	9.35 B	57.73 A	2.39 A	2.30 A	0.93 A	25.95 B	16.87 A	43.13 B	5.21 A	3.84 A	6.20 A
White original	19.82 a	10.03 b	56.37 a	7.52 bc	11.38 d	0.98 a	25.58 b	18.81 c	38.27 a	5.73 c	5.41 c	6.77 c
White recycled	28.68 b	9.35 b	55.04 a	8.42 d	20.58 f	1.05 a	24.79 b	21.06 e	36.86 a	6.21 d	5.26 c	6.96 c
Mean for white	24.25 B	9.69 B	56.13 A	7.97 C	15.98 C	1.01 A	25.19 B	19.94 B	37.57 A	5.97 B	5.34 B	6.87 B
Black original	29.90 b	6.31 a	59.51 a	7.77 c	18.42 e	1.81 b	23.16 a	19.86 d	36.24 a	6.41 e	5.93 d	7.58 d
Black recycled	31.30 b	6.43 a	71.04 a	7.19 b	21.49 g	3.04 c	24.54 b	20.33 d	37.57 a	6.28 de	5.35 c	7.73 d
Mean for black	30.60 C	6.37 A	65.27 A	7.48 B	19.96 D	2.43 B	23.85 A	20.10 B	36.90 A	6.34 C	5.64 C	7.66 C
Original[1]	21.46 X	7.53 X	62.89 X	7.50 X	9.99 X	2.00 X	25.06 X	19.40 X	39.98 X	5.89 X	5.31 Y	7.17 X
Recycled[1]	24.34 Y	7.73 X	65.38 X	7.49 X	13.25 Y	2.31 Y	25.31 X	19.74 X	40.58 X	5.81 X	5.04 X	7.11 X

[1] Means for the film material; Statistical analyses concerns each year separately, values designated with the same letters do not differ significantly; small letters concern interaction material x colour of film, capital letters – colour of film, X,Y – the film material.

Table 2

The effect of kind of plastic film used for shading on nitrate(III) reductase activity (NR, µmol NO_2^- · g^{-1} f.m. · h^{-1}), nitrate(V) ions (µmol NO_3^- · g^{-1} f.m.), ammonium ions (µmol NH_4^+ · g^{-1} f.m.) and free amino acids (mg N · 100 g^{-1} f.m.) content in celery stalks in 2005–2007

Kind of plastic film	Nitrate reductase activity			Nitrate ions			Ammonium ions			Free amino acids		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Control	18.88 eD	10.84bB	59.55cC	11.65cB	3.01 cC	2.65 aA	29.44cB	28.6 dD	39.10 aB	4.18 bB	5.02 dC	4.87 cB
Transparent original	11.20 d	4.51 a	52.64 c	7.75 a	1.38 a	2.32 a	30.76 d	23.16 c	37.26 a	3.60 a	3.70 c	3.78 b
Transparent recycled	16.52 e	6.04 a	58.08 c	8.45 b	1.24 a	3.73 b	29.21 c	23.0 c	42.64 b	3.57 a	3.10 a	3.49 ab
Mean for transparent	13.86 C	5.28 A	55.36 C	8.10 A	1.31 A	3.02 B	29.98 B	23.08 C	39.95 B	3.58 A	3.40 B	3.64 A
White original	6.16 b	3.82 a	37.83 b	15.30 d	2.15 b	5.01 c	25.23 a	18.65 a	36.84 a	4.73 c	3.26 b	3.75 b
White recycled	8.63 c	3.98 a	38.54 b	16.23 e	1.87 b	10.49 d	28.44 c	20.18 b	41.76 b	5.77 d	3.01 a	3.26 a
Mean for white	7.39 B	3.90 A	38.18 B	15.76 C	2.01 B	7.75 C	26.84 A	19.41 B	39.30 B	5.25 C	3.14 A	3.51 A
Black original	3.84 a	3.71 a	8.60 a	16.39 e	3.24 c	20.70 f	26.12 ab	18.0 a	36.90 a	7.57 e	8.44 e	6.23 d
Black recycled	3.56 a	3.19 a	8.30 a	18.82 f	4.04 d	16.77 e	26.80 b	17.3 a	38.01 a	7.83 f	9.55 f	6.75 e
Mean for black	3.70 A	3.45 A	8.45 A	18.82 D	3.64 D	18.74 D	26.46 A	17.65 A	37.46 A	7.70 D	9.00 D	6.49 C
Original[1]	10.02 X	5.72 X	39.65 X	12.77 X	2.44 X	7.67 X	27.89 X	22.11 X	37.53 X	5.02 X	5.11 X	4.66 X
Recycled[1]	11.90 Y	6.26 X	41.12 X	14.39 Y	2.54 X	8.41 Y	28.47 Y	22.28 X	40.38 Y	5.34 Y	5.17 X	4.59 X

[1] Means for the film material; Statistical analyses concerns each year separately, values designated with the same letters do not differ significantly; small letters concern interaction material x colour of film, capital letters – colour of film, X,Y – the film material.

stimulates synthesis *de novo* of this enzyme [4]. The dependence between nitrate reductase activity and nitrates was distinctly observed in the first and the last year of investigation. In 2006 because of very high temperatures in June the film shades had to be lifted what might have changed the results of NR activity. It is worthy to notice that preharvest plant shading with transparent film, regardless of its origin, caused a significant decrease of nitrates content in celery stalks. In 2005 and 2006 the level of these compounds was even lower than in the control. Another parameters presented in parallel work [14] indicate that this method of celery cultivation has an advantageous effect on improvement of yield quality.

Under black film shades poor nitrate metabolism in celery stalks was accompanied by low content of ammonium ions and the highest of free amino acids (Table 2). The last one might have been related to protein biosynthesis inhibition or catabolic processes increase after light intensity reduction. It has been shown recently that the level of total free amino acids is much higher in plants with fully deregulated nitrate reductase [15].

In both experiments no evident effect of film material (original or recycled) on nitrate metabolism was indicated. In the case of nitrate content the better effects were obtained with application of original material than the recycled one.

Conclusions

1. Nitrates content was the lowest in celery stalks of plants grown in tunnels covered with transparent film.

2. In experiment with plant shading two weeks before harvest, in most cases, with the reducing of film transmission for light the decrease of nitrate reductase activity and increase of nitrates in celery stalks was shown.

3. In stalks of celery shaded with black films at the final stage of growing period the lower level of ammonium ions and the highest of free amino acids was shown.

4. The film colour had greater effect on nitrate content and its metabolism than material of the film.

References

[1] Najda A. and Dyduch J.: Zesz. Nauk. AR, Wrocław 2005, **515**, 363–367.
[2] Michalik Ł.: Zesz. Probl. Post. Nauk Roln. 2008, **527**, 213–219.
[3] Siwek P.: 2002, Zesz. Nauk. AR, Kraków, ser. Rozprawy **279**, 1–96.
[4] Lillo C., Meyer Ch., Lea U.S., Provan F. and Oltedal S.: J. Exp. Bot. 2004, **55**(401), 1275–1282.
[5] Wojciechowska R. and Siwek P.: Folia Hort. 2006, **18**(2), 25–35.
[6] Opinion of the Scientific Panel on Contaminants in the Food chain on a request from the European Commission to perform a scientific assessment on nitrate in vegetables. The EFSA Journal, 2008, **689**, 1–79.
[7] Martignon G., Casarotti D., Venezia A., Schiavi M. and Malorgio F.: Acta Hort. 1994, **361**, 583–589.
[8] Siwek P., Wojciechowska R., Pilarski J. and Libik A.: Zesz. Probl. Post. Nauk Roln. 2006, **509**, 343–351.
[9] Rożek S.: Acta Physiol. Plant. 1982, **4**, 81–90.
[10] Korenman S.: Analiza fotometryczna. WNT, Warszawa 1973.
[11] Siwek P., Wojciechowska R., Libik A. and Kalisz A.: Veg. Crop Res. Bull. 2009, **70**, 91–100.
[12] Kenis J.D., Rouby M.B., Edelman M.O. and Silvente S.T.: J. Plant Physiol. 1994, **144**, 735–739.

[13] Wojciechowska R. and Siwek P.: Folia Hort. 2007, **19**(2), 99–107.
[14] Siwek P., Wojciechowska R., Kalisz A., Libik A. and Gryza I.: Ecol. Chem. Eng. 2011 (in press).
[15] Lea U.S., Leydecker M.T. Quillere I., Meyer C. and Lillo C.: Plant Physiol. 2006, **140**, 1085–1094.

WPŁYW FOLII STOSOWANEJ W TUNELACH NISKICH ORAZ DO CIENIOWANIA NA METABOLIZM AZOTANÓW W OGONKACH LIŚCIOWYCH SELERA NACIOWEGO

Wydział Ogrodniczy
Uniwersytet Rolniczy w Krakowie

Abstrakt: Przedstawiono wyniki trzyletnich badań (2005–2007) nad wpływem folii polietylenowej wykonanej z surowca oryginalnego i recyklingowego (bezbarwnej, białej i czarnej) wykorzystanej do pokrycia tuneli niskich oraz do cieniowania roślin przed zbiorem na metabolizm azotanów w ogonkach liściowych selera naciowego odmiany 'Tango'. Wykonano oznaczenia zawartości azotanów, aktywności reduktazy azotanowej, jak również zawartości jonów amonowych oraz wolnych aminokwasów. W pierwszym doświadczeniu rośliny selera rosły w tunelach od wysadzenia rozsady, po czym około miesiąc przed zbiorem zdejmowano folie, a w drugim – folie rozciągano na konstrukcji tuneli niskich na dwa tygodnie przed zbiorem.

Zawartość i przemiany azotanów były bardziej modyfikowane w doświadczeniu drugim; wraz ze zmniejszaniem się przepuszczalności folii dla PAR stwierdzono znaczny spadek aktywności reduktazy azotanowej w ogonkach liściowych selera. W obu eksperymentach najniższy poziom azotanów odnotowano w ogonkach selera, zebranych spod folii bezbarwnych. Największą zawartość wolnych aminokwasów obserwowano w kombinacjach z folią czarną. Większy wpływ na zawartość i przemiany azotanów miało zabarwienie użytych folii niż materiał, z którego je wykonano.

Słowa kluczowe: folia bezbarwna, biała i czarna, azotany, reduktaza azotanowa, jony amonowe

ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

Krzysztof WRAGA[1] and Monika PLACEK[1]

USE OF MEDIA SUPPLEMENTED WITH COMPOST CONTAINING POTATO PULP IN CULTIVATION OF EGYPTIAN STAR CLUSTER (*Pentas lanceolata* (Forssk.) Deflers)

ZASTOSOWANIE PODŁOŻY WZBOGACONYCH W KOMPOST ZAWIERAJĄCY WYCIERKĘ ZIEMNIACZANĄ W UPRAWIE PIĄTAKA LANCETOWATEGO (*Pentas lanceolata* (Forssk.) Deflers)

Abstract: Two experiments were carried out in the years 2005–2006 to examine if media supplemented with 20, 40 or 60 % compost containing 70 % potato pulp and 30 % rye straw can be used in cultivation of three cultivars of *Pentas lanceolata*. In the first experiment compost after 7 months of composting process was used and in the second experiment compost after 19 months of composting process was used.

It was found that mixtures of 20 % compost and 80 % sphagnum peat can be recommended for Egyptian star cluster cultivation. Plants cultivated in such media were healthy, well-formed and blossomed abundantly. Media containing 40 and 60 % compost were characterized by too high macroelements content and by too salinity. Plants cultivated in such media were small and blossomed poorly.

Keywords: *Pentas lanceolata*, compost, potato pulp, cultivation

Resources of sphagnum peat are getting smaller and new media or media components are sought-after to replace sphagnum peat in horticultural production. Waste material from food industry: cocoa hulls, rice chaff and potato pulp; wood industry: pine bark and sawdust; and municipal waste: sewage sludge are used first of all [1–6].

Potato pulp contains macroelements (nitrogen, phosphorus, potassium) and that is why it can be used as an organic fertilizer or a component of composts supplemented with sewage sludge [7, 8]. Potato pulp is often composted with some structure-forming material such sawdust or straw to improve its physical properties [7–9].

Egyptian star cluster is a half-shrub, cultivated as a pot plant, which belongs to the family *Rubiaceae*. Dark-green leaves and star-shaped flowers are decorative

[1] Department of Horticulture, Section of Ornamental Plants, West Pomeranian University of Technology in Szczecin, ul. Papieża Pawła V/1, 71–459 Szczecin, Poland, phone: +48 91 449 63 54, email: krzysztof.wraga@zut.edu.pl

elements of that species. Its cultivars are characterized by white, purple-red or pink flowers [10].

The aim of conducted experiments was to examine the possibilities of the use of compost containing potato pulp and straw in *Pentas lanceolata* cultivation.

Material and methods

Two pot experiments were carried out in the years 2005–2006. The experimental factors were: medium and cultivar.

Production of compost used in the experiments started in September 2004. Compost contained 70 % potato pulp and 30 % rye straw cut into pieces of 5–6 cm length. Compost components were well mixed and put into a plastic container in a storage room.

The following assessments of potato pulp, rye straw and compost after 7 months of composting process were made: dry matter content, pH (in H_2O), total content of N, P, K, Ca and Mg as well as organic C content with methods usual used in agricultural chemistry [11]. Dry matter content was estimated by the method of drying to the stable weight (105 ^oC), pH (in H_2O) by the potentiometric method, total N by Kjeldahl method, total P by the colorimetric method, total K and Ca by the flame photometry method, Mg by the atomic spectrometry absorption method and organic C by Tiurin method.

In the first experiment compost after 7 months of composting process was used and in the second experiment compost after 19 months of composting process was used as a component of media for *Pentas lanceolata* grow. The following assessments of media used in the experiments were made: pH (in H_2O), salinity, NO_3-N, available forms of P, K, Ca and Mg. Content of NO_3-N was assessed by the ionometric method, P – by the colorimetric method, K and Ca – by the flame photometry method, Mg – by the method of atomic spectrometry absorption. In both years of studies chemical analyses of media were carried out in the first decade of July, before seedlings planting.

In both years of experiments three cultivars of *Pentas lanceolata*: 'Graffiti Pink F_1', 'Graffiti Violet F_1' and 'Graffiti White F_1' were the test plants. Seeds of *Pentas lanceolata* were sown in the first decade of May. Two months later seedlings were planted to 12-cm pots (V = 1.0 dm^3). Four medium variants were used: 1 – sphagnum peat adjusted to pH 6.9 (in the first year of studies) and to pH 6.6 (in the second year of studies), supplemented with 5 g · dm^{-3} of slow-release fertilizer Osmocote Exact 3-4 Standard (16 + 11 + 11 + microelements); 2–4 – mixtures of compost and sphagnum peat: 2–20 % compost + 80 % sphagnum peat, 3–40 % compost + 60 % sphagnum peat, 4–60 % compost + 40 % sphagnum peat. Compost and sphagnum peat were mixed in a volumetric relation. No fertilizer was added to the mixtures of compost and peat before seedlings planting.

Plants were cultivated in a greenhouse. In the second decade of July and in the second decade of August all experimental plants were fertilized with a water solution of Peters Professional (15 + 11 + 29) in concentration of 0.2 % and in a dose of 100 cm^3 per plant. In the second half of September (in full flowering) the measurements of plants height, diameter and number of inflorescences were conducted. Greenness index of leaves was also measured by the means of Chlorophyll Meter SPAD-502.

The method of complete randomization in five repetitions was used. Twelve plants were in each experimental object. The results of the experiments were worked out using the analysis of variance for two-factorial experiments. The differences between means were verified by Tukey's test at the significance level of $\alpha = 0.05$.

Results and discussion

Selected properties of compost components and of prepared compost after 7 months of composting process are given in Table 1.

Table 1

Selected properties of components used for compost production and of prepared compost after 7 months of composting process

Component	Dry matter [%]	pH in H_2O	Total content					Organic C
			N	P	K	Ca	Mg	
			[$g \cdot kg^{-1}$ d.m.]					
Potato pulp	13.51	4.5	6.60	2.96	11.50	6.32	1.04	102
Straw	86.05	—	4.65	3.85	7.41	0.90	0.21	254
Compost	21.80	5.6	6.56	2.50	11.40	1.96	0.89	250

It was found that potato pulp contained more N, K, Ca and Mg than straw. However, straw was characterized by higher total content of P and organic C and over 6.5 times higher content of dry matter than potato pulp. After 7 months of composting process compost containing 70 % potato pulp and 30 % rye straw contained 21.80 % dry matter and was characterized by pH 5.6. Compost contained 6.56 g total N, 2.50 g total P and 11.40 g total K per 1 kg^{-1} d.m. (Table 1).

Selected properties of all media used in both years of studies are given in Table 2.

Evaluated mixtures of compost and sphagnum peat were characterized by higher pH in the first year of the experiments than in the second (Table 2). In both years an increase of compost content in media caused a decrease of media pH value and an increase of its salinity. Salt concentration of media supplemented with compost was higher in the first year of studies than in the second. Macroelements content (nitrate nitrogen, phosphorus, potassium) was higher in the first year of experiments than in the second.

In both years of experiments significant influence of medium on total height and diameter of plants was shown (Table 3).

In the first year control plants were the highest (18.8 cm), even too high for horticultural production and of the greatest diameter (24.3 cm) (Table 3). Plants cultivated in mixtures containing 20 and 40 % compost were more compact and

Table 2

Selected properties of media used in the experiments before seedlings planting

Medium	pH in H_2O	Salinity [g NaCl · dm^{-3}]	NO_3-N	P	K	Ca	Mg
			[mg · dm^{-3}]				
2005							
1	6.9	0.39	52	22	49	2353	318
2	6.3	3.61	237	189	255	2312	320
3	5.9	5.26	566	305	355	2299	326
4	5.1	5.28	678	325	607	2237	351
2006							
1	6.6	1.31	25	53	60	2683	338
2	5.4	2.95	158	150	210	2361	401
3	5.3	3.68	233	210	256	2410	332
4	4.5	4.12	432	199	353	2119	315

Explanations: 1 – sphagnum peat; 2 – 20 % compost + 80 % sphagnum peat; 3 – 40 % compost + 60 % sphagnum peat; 4 – 60 % compost + 40 % sphagnum peat.

Table 3

Effects of media containing compost on height and diameter of three cultivars of *Pentas lanceolata*

Medium (A)	2005				2006			
	Cultivar (B)			Mean (A)	Cultivar (B)			Mean (A)
	Graffiti Pink	Graffiti Violet	Graffiti White		Graffiti Pink	Graffiti Violet	Graffiti White	
Height [cm]								
1	18.0	18.9	19.5	18.8	21.4	20.8	20.4	20.9
2	14.0	16.0	17.4	15.8	20.9	20.7	20.5	20.7
3	15.2	16.0	17.2	16.1	20.0	20.0	19.8	19.9
4	12.1	14.0	13.0	13.0	19.4	17.9	19.2	18.8
Mean (B)	14.8	16.2	16.8		20.4	19.9	20.0	
$LSD_{0.05}$	A – 0.93; B – 0.73; A(B) – 1.60; B(A) – 1.46				A – 1.37; B – n.s.; A · B – n.s.			
Plant diameter [cm]								
1	24.6	25.6	22.8	24.3	24.4	25.2	23.4	24.3
2	18.7	15.1	16.0	16.6	23.6	23.4	23.0	23.3
3	18.0	15.0	15.7	16.2	23.0	22.8	21.2	22.3
4	15.6	11.6	14.0	13.7	19.2	19.0	16.6	18.3
Mean (B)	19.2	16.8	17.1		22.6	22.6	21.1	
$LSD_{0.05}$	A – 1.66; B – 1.30; A(B) – 2.87; B(A) – 2.61				A – 1.44; B – 1.13; A · B – n.s.			

Explanations: 1 – sphagnum peat supplemented with 5 g · dm^{-3} Osmocote Exact 3-4 Standard; 2 – 20 % compost + 80 % sphagnum peat; 3 – 40 % compost + 60 % sphagnum peat; 4 – 60 % compost + 40 % sphagnum peat; n.s. – not significant difference.

proportional than control plants. They were on the average by 18 % lower and were characterized by 48 % smaller diameter than control plants. Whereas, plants cultivated in medium containing 60 % compost were the smallest. They were only of 13.0 cm height and of 13.7 cm diameter.

In the second year of experiments, similarly to the first year, control plants were too high (20.9 cm) and of the greatest diameter (24.3 cm) however, plants cultivated in medium supplemented with 60 % compost were too small. It was probably caused by high salt concentration in media supplemented with compost. Plants growth inhibition caused by media salinity was also often observed on many species [12]. Jaleel et al [13] observed it on *Catharanthus roseus* and Turhan et al [14] on *Helianthus annuus*. Lee and van Iersel [15] are of the opinion that salinity has a potential to act as a growth regulator in chrysanthemum cultivation because of its ability to reduce plant height with only a small reduction in shoot dry weight.

Results of these experiments are conformable with results of Placek et al [16] that garden pansies cultivated in media supplemented with composts (also containing potato pulp and straw) are characterized by smaller diameter, but their growth and conformation are proper. In both years of these experiments plants cultivated in mixtures of 20 % compost and 80 % sphagnum peat were lower and of smaller diameter than control plants, but they were characterized by higher decorative value. They were compact, well-formed and of proportional conformation. No overcolouring or deformation of leaves were found.

In the first year of studies among three examined cultivars of *Pentas lanceolata* 'Graffiti Violet F_1' and 'Graffiti White F_1' were by 12 % higher and by 13 % less branchy than 'Graffiti Pink F_1'. In the second year of experiments evaluated cultivars did not differ in total height of plants. Plants 'Graffiti Pink F_1' and 'Graffiti Violet F_1' were characterized by 7 % greater diameter than plants 'Graffiti White F_1'.

In the first year of studies significant influence of medium on the greenness index of leaves was shown (Table 4). Leaves of plants cultivated in media containing compost, especially in quantity of 20 %, were darker than leaves of control plants. They were characterized by the highest greenness index of leaves (51.5). Greenness index of leaves of control plants was the lowest and amounted to 49.0. No significant influence of medium on greenness index of leaves in the second year of studies was found.

Among examined cultivars of *Pentas lanceolata* 'Graffiti Pink F_1' was characterized by the highest greenness index of leaves in both years of experiments (53.8 and 52.2, respectively).

According to Martin et al [17], who examined some species of ornamental shrubs, greenness index of leaves indicates nitrogen content in leaves. In these experiments media supplemented with compost were characterized by high content of nitrogen and probably that was why plants cultivated in these media were characterized by high greenness index of leaves.

In both years of studies number of inflorescences depended significantly on medium (Table 4). In the first year of experiments control plants were characterized by the greatest number of inflorescences (8.8). Plants cultivated in medium containing 20 % compost had by 26 % less inflorescences than control plants. Plants cultivated in media supplemented with 40 or 60 % compost had over twice less inflorescences than plants in the control object. In the second year of studies control plants and those cultivated in medium containing 20 % compost flowered the most abundantly (had 9.5 and 8.7 inflorescences, respectively). Plants cultivated in mixture of 60 % compost and 40 % sphagnum peat flowered poorly and had on average only 4.2 inflorescences. Results of these experiments are unconformable with results of experiments conducted by Placek et al [18] where garden pansies cultivated in media containing composts supplemented with potato pulp and straw blossomed more abundantly than control plants, cultivated in sphagnum peat. Flowers of pansies cultivated in mixtures of composts and sphagnum peat were often characterized by greater diameter than control plants.

Table 4

Effects of media containing compost on greenness index of leaves and number of inflorescences of three cultivars of *Pentas lanceolata*

Medium (A)	2005				2006			
	Cultivar (B)			Mean (A)	Cultivar (B)			Mean (A)
	Graffiti Pink	Graffiti Violet	Graffiti White		Graffiti Pink	Graffiti Violet	Graffiti White	
Greenness index of leaves (SPAD)								
1	50.4	49.1	47.4	49.0	51.7	49.9	48.0	49.9
2	56.0	52.3	54.5	54.3	52.5	51.2	50.7	51.5
3	54.7	46.3	53.4	51.5	52.4	50.0	50.5	51.0
4	54.0	44.4	51.2	49.9	52.1	49.5	49.8	50.5
Mean (B)	53.8	48.0	51.6		52.2	50.2	49.8	
$LSD_{0.05}$	A – 2.08; B – 1.64; A(B) – 3.61; B (A) – 3.28				A – n.s.; B – 1.31; A · B – n.s.			
Number of inflorescences								
1	9.0	9.2	8.2	8.8	9.8	10.2	8.6	9.5
2	6.8	8.0	6.2	7.0	9.2	9.8	7.2	8.7
3	3.2	5.0	4.6	4.3	7.4	5.0	7.2	6.5
4	5.0	2.0	3.0	3.3	4.2	4.0	4.4	4.2
Mean (B)	6.0	6.1	5.5		7.7	7.3	6.9	
$LSD_{0.05}$	A – 1.44; B – n.s.; A(B) – 2.49; B (A) – 2.26				A –1.13; B – n.s.; A(B) – 1.96; B(A) – 1.78			

Explanations: see Table 3.

According to Krzywy-Gawronska [19] potato pulp can be used as a component of composts with structure-forming materials, for example with rye straw. On the basis of the obtained results and chemical analyses of media used in these experiments (Tables 2–4) it was found that medium supplemented with 20 % compost was the most favorable for *Pentas lanceolata*. Media containing 40 % and 60 % compost were characterized by too high macroelements content, especially nitrogen, for Egyptian star cluster. These media were also characterized by concentration of salt which Strojny [20] finds too high or even harmful for plants.

Conclusions

1. Media containing 20 % compost and 80 % sphagnum peat are the most favorable for Egyptian star cluster. Plants cultivated in such media are well-formed, compact, blossom abundantly and are characterized by high greenness index of leaves.

2. Media with addition of 40 or 60 % compost are characterized by too high macroelements content and by too high salinity for *Pentas lanceolata* grow. Plants cultivated in such media are small and blossom poorly, even though are characterized by high greenness index of leaves.

References

[1] Czekalski M.: Ogólna uprawa roślin ozdobnych. Wyd. AR Wrocław, Wrocław 2005, 268 p.
[2] Mupondi L.T., Mnkeni P.N.S. and Brutsch M.O.: Compost Sci. Util. 2006, **14**(4), 238–243.
[3] Startek L., Placek M. and Klessa M.: Zesz. Probl. Post. Nauk Roln. 2006, **510**, 609–617.
[4] Wraga K. and Zawadzińska A.: Ochr. Środow. Zasob. Natur. 2007, **31**, 249–254.
[5] Zawadzińska A. and Klessa M.: Zesz. Probl. Post. Nauk Roln. 2007, **518**, 209–217.
[6] Dobrowolska A. and Janicka D.: Zesz. Probl. Post. Nauk Roln. 2008, **525**, 89–96.
[7] Krzywy-Gawrońska E.: Zesz. Probl. Post. Nauk Roln. 2006, **512**, 363–368.
[8] Krzywy E., Zawadzińska A. and Klessa M.: Zesz. Probl. Post. Nauk Roln. 2007, **518**, 101–110.
[9] Krzywy E. and Krzywy J.: Zesz. Probl. Post. Nauk Roln. 2003, **494**, 233–239.
[10] Schripsema J., Caprini G.P., van der Heijden der R., Bino R., de Vos R. and Dagnino D.: J. Nat. Prod. 2007, **70**, 1495–1498.
[11] Ostrowska A., Gawliński S. and Szczubiałka Z.: Metody analizy i oceny właściwości gleb i roślin – Katalog. Wyd. IOŚ, Warszawa 1991, 334 p.
[12] Leone A.P., Menetti M. and Sorrentino G.: Italian J. Agron. 2001, **4**(2), 75–85.
[13] Jaleel C.A., Sankar B., Sridharan R. and Panneerselvam R.: Turk. J. Biol. 2008, **32**, 79–93.
[14] Turhan H., Genc L., Smith S.E., Bostanci Y.B. and Turkmen O.S.: Afr. J. Biotechnol. 2008, **7**(6), 750–756.
[15] Lee M.K. and van Iersel M.W.: HortScience 2008, **43**(6), 1888–1891.
[16] Placek M., Janicka D. and Piechocki R.: Folia Univ. Agric. Stetin., Agric., Aliment., Pisc., Zootech. 2008, **262**, 93–100.
[17] Martin I., Alonso N., Lopez M., Prieto M., Cadahia C. and Eymar E.: Commun. Soil Sci. Plan. 2007, **38**(13–14), 1785–1803.
[18] Placek M., Janicka D. and Piechocki R.: Folia Univ. Agric. Stetin., Agric., Aliment., Pisc., Zootech. 2008, **262**, 101–108.
[19] Krzywy-Gawrońska E.: Zesz. Probl. Post. Nauk Roln. 2006, **512**, 369–379.
[20] Strojny Z.: Nawożenie roślin ozdobnych pod osłonami. Centrum Ogrodnicze, Skierniewice 1993, 112 p.

ZASTOSOWANIE PODŁOŻY WZBOGACONYCH W KOMPOST ZAWIERAJĄCY WYCIERKĘ ZIEMNIACZANĄ W UPRAWIE PIĄTAKA LANCETOWATEGO (*Pentas lanceolata* (Forssk.) Deflers)

Katedra Ogrodnictwa, Pracownia Roślin Ozdobnych
Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Abstrakt: W latach 2005–2006 przeprowadzono dwa doświadczenia, których celem było zbadanie, czy podłoża z dodatkiem 20, 40 lub 60 % kompostu zawierającego 70 % wycierki ziemniaczanej i 30 % słomy żytniej mogą być stosowane w uprawie trzech odmian piątaka lancetowatego. W doświadczeniu I zastosowano kompost po 7 miesiącach kompostowania, a w doświadczeniu II kompost po 19 miesiącach kompostowania.

Stwierdzono, że mieszanki 20 % kompostu i 80 % torfu wysokiego mogą być polecane do uprawy piątaka lancetowatego. Rośliny uprawiane w takich podłożach były zdrowe, prawidłowo uformowane i kwitły obficie. Podłoża zawierające 40 i 60 % kompostu charakteryzowały się zbyt dużą zawartością makroelementów i zbyt dużym zasoleniem. Rośliny uprawiane w tych podłożach były niewielkie i kwitły słabo.

Słowa kluczowe: *Pentas lanceolata*, kompost, wycierka ziemniaczana, uprawa

Varia

INNOWACYJNA GOSPODARKA
NARODOWA STRATEGIA SPÓJNOŚCI

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ
ROZWOJU REGIONALNEGO

INFORMACJA O PROJEKCIE „WYKORZYSTANIE KAPUSTY BIAŁEJ NA POTRZEBY FITOREMEDIACJI I BIOFUMIGACJI GLEBY (AGROBIOKAP)”

Projekt nr UDA-POIG.01.03.01-00-138/09
współfinansowany przez Unię Europejską
ze środków Europejskiego Funduszu Rozwoju Regionalnego
w ramach Programu Operacyjnego Innowacyjna Gospodarka, 2007–2013

Oś priorytetowa 1.:	Badania i rozwój nowoczesnych technologii
Działanie 1.3.:	Wsparcie projektów B+R na rzecz przedsiębiorstw realizowanych przez jednostki naukowe
Poddziałanie 1.3.1.:	Projekty rozwojowe
Rekomendowana kwota dofinansowania:	3 391 950,00 PLN
Termin realizacji projektu:	01.07.2007–01.07.2013

Cele projektu:

- opracowanie innowacyjnej i ekonomicznej technologii fitoremediacji terenów zdegradowanych;
- produkcja naturalnego środka do biofumigacji gleb użytkowanych rolniczo i ogrodniczo.

Zadania badawcze projektu:

- przeprowadzanie badań fizjologicznych kapusty z upraw prowadzonych w różnych warunkach;
- opracowanie technologii uprawy kapusty;
- badania analityczne w celu określenia wpływu warunków uprawy kapusty na zawartość związków bioaktywnych i biokumulację metali ciężkich w kapuście;
- statystyczne opracowanie wyników pomiarów;
- opracowanie technologii otrzymywania biopreparatu zgodnie z wymogami przemysłu;
- zaproponowanie metod zagospodarowania odpadu po produkcji biopreparatu.

Kontakt:
Wydział Chemiczny Politechniki Gdańskiej
ul. G. Narutowicza 11/12, 80–233 Gdańsk
tel./fax.0048 58 347 26 25
e-mail: agrobiokap@chem.pg.gda.pl
http://www.chem.pg.gda.pl/agrobiokap/

Invitation for ECOpole '11 Conference

CHEMICAL SUBSTANCES IN ENVIRONMENT

We have the honour to invite you to take part in the 20th annual Central European Conference ECOpole '11, which will be held in **12–15 X 2011** (Thursday–Saturday) at the Conference Center "Rzemieślnik" in Zakopane, PL.

The Conference Programme includes oral presentations and posters and will be divided into five sections:

– SI Chemical Pollution of Natural Environment and Its Monitoring
– SII Environment Friendly Production and Use of Energy
– SIII Risk, Crisis and Security Management
– SIV Forum of Young Scientists and Environmental Education in Chemistry
– SV Impact of Environment Pollution on Food and Human Health

The Conference language is English.

Contributions to the Conference will be published as:

– abstracts on the CD-ROM (0.5 page of A4 paper sheet format)
– extended Abstracts (4–6 pages) in the semi-annual journal *Proceedings of ECOpole*
– full papers will be published in successive issues of the *Ecological Chemistry and Engineering/Chemia i Inżynieria Ekologiczna* (Ecol. Chem. Eng.) ser. A or S.

Additional information one could find on the Conference website:

ecopole.uni.opole.pl

The deadline for sending the Abstracts is **15.07.2011** and for the Extended Abstracts: **1.10.2011**. The actualised list (and the Abstracts) of the Conference contributions accepted for presentation by the Scientific Board, one can find (starting from 15.07.2011) on the Conference website.

The papers must be prepared according to the Guide for Authors on Submission of Manuscripts to the Journals.

At the Reception Desk each participant will obtain a CD-ROM with abstracts of the Conference contributions as well as Conference Programme (the Programme will be also published on this site).

Further information is available from:
Prof. dr hab. Maria Wacławek
Chairperson of the Organising Committee
of ECOpole '11 Conference
University of Opole
email: Maria.Waclawek@o2.pl
and mrajfur@o2.pl
phone +48 77 455 91 49 and +48 77 401 60 42
fax +48 77 401 60 51

Zapraszamy
do udziału w Środkowoeuropejskiej Konferencji
ECOpole '11
w dniach 12–15 X 2011

SUBSTANCJE CHEMICZNE W ŚRODOWISKU PRZYRODNICZYM

Będzie to dziewiętnasta z rzędu konferencja poświęcona badaniom podstawowym oraz działaniom praktycznym dotycząca różnych aspektów ochrony środowiska przyrodniczego. Odbędzie się ona w Ośrodku Konferencyjno-Wypoczynkowym „Rzemieślnik" w Zakopanem.

Doroczne konferencje ECOpole mają charakter międzynarodowy i za takie są uznane przez Ministerstwo Nauki i Szkolnictwa Wyższego.

Obrady konferencji ECOpole '11 będą zgrupowane w pięciu sekcjach:
– SI Chemiczne substancje w środowisku przyrodniczym oraz ich monitoring
– SII Odnawialne źródła energii i jej oszczędne pozyskiwanie oraz użytkowanie
– SIII Zarządzanie środowiskiem w warunkach kryzysowych
– SIV Forum Młodych (FM) i Edukacja prośrodowiskowa
– SV Wpływ zanieczyszczeń środowiska oraz żywności na zdrowie ludzi.

Materiały konferencyjne będą opublikowane w postaci:
– abstraktów (0,5 strony formatu A4) na CD-ROM-ie;
– rozszerzonych streszczeń o objętości 4-6 stron w półroczniku *Proceedings of ECOpole*;
– artykułów: w abstraktowanych czasopismach: *Ecological Chemistry and Engineering/Chemia i Inżynieria Ekologiczna* (*Ecol. Chem. Eng.*) ser. A i S oraz niektórych w półroczniku *Chemia – Dydaktyka – Ekologia – Metrologia*.

Termin nadsyłania angielskiego i polskiego streszczenia o objętości 0,5–1,0 strony (wersja cyfrowa + wydruk) planowanych wystąpień upływa w dniu 15 lipca

2011 r. Lista prac zakwalifikowanych przez Radę Naukową Konferencji do prezentacji będzie sukcesywnie publikowana od 15 lipca 2011 r. na stronie webowej

ecopole.uni.opole.pl

Aby praca (dotyczy to także streszczenia, które powinno mieć tytuł w języku polskim i angielskim, słowa kluczowe w obydwu językach) przedstawiona w czasie konferencji mogła być opublikowana, jej tekst winien być przygotowany zgodnie z wymaganiami stawianymi artykułom drukowanym w czasopismach *Ecological Chemistry and Engineering* ser. A oraz S, które jest dostępne w wielu bibliotekach naukowych w Polsce i za granicą. Są one takie same dla prac drukowanych w półroczniku *Chemia – Dydaktyka – Ekologia – Metrologia*. Zalecenia te są również umieszczone na stronie webowej konferencji.

Po konferencji zostaną wydane 4–6-stronicowe rozszerzone streszczenia wystąpień w półroczniku *Proceedings of ECOpole*. Artykuły te winny być przesłane do **1 października 2011 r**. Wszystkie nadsyłane prace podlegają zwykłej procedurze recenzyjnej. Wszystkie streszczenia oraz program Konferencji zostaną wydane na CD-ROM-ie, który otrzyma każdy z uczestników podczas rejestracji. Program będzie także umieszczony na stronie webowej Konferencji.

Prof. dr hab. Maria Wacławek
Przewodnicząca Komitetu Organizacyjnego
Konferencji ECOpole '11

Wszelkie uwagi i zapytania można kierować na adres:
Maria.Waclawek@o2.pl
lub mrajfur@o2.pl
tel. 77 401 60 42 i 77 455 91 49
fax 77 401 60 51

GUIDE FOR AUTHORS
ON SUBMISSION OF MANUSCRIPTS

A digital version of the Manuscript addressed –

Professor Witold Wacławek
Editorial Office of monthly *Ecological Chemistry and Engineering*
(Ecol. Chem. Eng.)
Uniwersytet Opolski
ul. kard. B. Kominka 4, 45–032 Opole, Poland
Phone +48 77 401 60 42, fax +48 77 401 60 51,
Email – waclawek@uni.opole.pl

should be sent by email to the Editorial Office Secretariat – mrajfur@o2.pl

The Editor assumes, that an author submitting a paper for publication has been authorised to do that. It is understood the paper submitted to be original and unpublished work, and is not being considered for publication by another journal. After printing, the copyright of the paper is transferred to *Towarzystwo Chemii i Inżynierii Ekologicznej* (*Society for Ecological Chemistry and Engineering*). In preparation of the manuscript please follow the general outline of papers published in the most recent issues of *Ecol. Chem. Eng*., a sample copy can be sent, if requested.

Papers submitted are supposed to be written in English language and should include a summary and keywords, if possible also in Polish language. If not then the Polish summary and keywords will be provided by the Editorial Office. All authors are requested to inform of their current addresses, phone and fax numbers and their email addresses.

It is urged to follow the units recommended by the *Systéme Internationale d'Unites* (SI). Graph axis labels and table captions must include the quantity units. The use of the following commonly applied expressions is recommended: mass – m/kg, time – t/s or t/min, current intensity – I/A; thermodynamic temperature – T/K, Celsius scale temperature – t/°C or θ/°C (if both time and Celsius scale units need to be used, the symbol θ/°C for temperature is to be taken) etc.

Symbols recommended by the International Union of Pure and Applied Chemistry (Pure and Appl. Chem., 1979, **51**, 1–41) are to be followed.

Graphics (drawings, plots) should also be supplied in the form of digital vector – type files, *e.g*. Corel-Draw, Grapher for Windows or at least in a bitmap format (TIF, PCK, BMP). In the case of any query please feel free to contact with the Editorial Office.

Footnotes, tables and graphs should be prepared as separate files.

References cited chronologically should follow the examples given below:

[l] Kowalski J. and Malinowski A.: Polish J. Chem. 1990, **40**(3), 2080–2085.

[2] Nowak S: Chemia nieorganiczna, WNT, Warszawa 1990.

[3] Bruns I., Sutter K., Neumann D. and Krauss G.-J.: *Glutathione accumulation – a specific response of mosses to heavy metal stress*, [in:] Sulfur Nutrition and Sulfur Assimilation in Higher Plants, P. Haupt (ed.), Bern, Switzerland 2000, 389–391.

Journal titles should preferably follow the Chem. Abst. Service recommended abbreviations.

Receipt of a paper submitted for publication will be acknowledged by email. If no acknowledgement has been received, please check it with the Editorial Office by email, fax, letter or phone.

ZALECENIA DOTYCZĄCE PRZYGOTOWANIA MANUSKRYPTÓW

Praca przeznaczona do druku w miesięczniku *Ecological Chemistry and Engineering A/Chemia i Inżynieria Ekologiczna A* powinna być przesłana na adres Redakcji:

Profesor Witold Wacławek
Redakcja Ecological Chemistry and Engineering
Uniwersytet Opolski
ul. kard. B. Kominka 4, 45–032 Opole
tel. 077 401 60 42, fax 077 401 60 51
email: waclawek@uni.opole.pl

w postaci cyfrowej w formacie Microsoft Word (ver. 7.0 dla Windows) emailem (mrajfur@o2.pl) lub na dyskietce.

Redakcja przyjmuje, że przesyłając artykuł do druku autor w ten sposób oświadcza, że jest upoważniony do tego oraz zapewnia, że artykuł ten jest oryginalny i nie był wcześniej drukowany gdzie indziej i nie jest wysłany do druku gdzie indziej oraz, że po jego wydrukowaniu copyright do tego artykułu uzyskuje Towarzystwo Chemii i Inżynierii Ekologicznej.

W przygotowaniu manuskryptu należy przede wszystkim wzorować się na postaci najnowszych artykułów opublikowanych w *Ecological Chemistry and Engineering*, na przykład zamieszczanych na stronie webowej Towarzystwa:

http://tchie.uni.opole.pl/

Prace przesyłane do publikacji winny być napisane w języku angielskim oraz zaopatrzone w streszczenia oraz słowa kluczowe w języku angielskim oraz polskim.

Zalecamy, ażeby artykuł zawierał adresy i emaile oraz numery telefonów i faksów wszystkich autorów danej pracy, szczególnie głównego autora, którego nazwisko wyróżniamy gwiazdką.

Usilnie prosimy o stosowanie układu jednostek SI. Zwracamy uwagę, że osie wykresów oraz główki tabel powinny bezwzględnie zawierać jednostki stosownej wielkości. Polecamy symbolikę zalecaną przez PTChem (Symbole i terminologia wielkości i jednostek stosowanych w chemii fizycznej, Ossolineum, Wrocław 1989; Pure Appl. Chem. 1979, **51**, 1–41). Materiał graficzny (rysunki, wykresy), obok wersji na papierze, powinien również być dostarczony w postaci cyfrowych plików wektorowych, np. za pomocą programu: CorelDraw wersja 3.0–8.0, Grafer dla Windows lub przynajmniej bitowe (TIF, PCX, BMP). W przypadku trudności z wypełnieniem tego warunku Redakcja zapewnia odpłatne wykonanie materiału graficznego na podstawie dostarczonego szkicu, bliższe informacje można uzyskać telefonicznie 077 401 60 42.

Przypisy i tabele podobnie jak rysunki zapisujemy jako osobne pliki.

Literaturę prosimy zamieszczać wg poniższych przykładów:

[1] Kowalski J. and Malinowski A.: Polish J. Chem. 1990, **40**, 2080–2085.

[2] Nowak S.: Chemia nieorganiczna, WNT, Warszawa 1990.

[3] Bruns I., Sutter K., Neumann D. and Krauss G.-J.: *Glutathione accumulation – a specific response of mosses to heavy metal stress*, [in:] Sulfur Nutrition and Sulfur Assimilation in Higher Plants, P. Haupt (ed.), Bern, Switzerland 2000, 389–391.

Tytuły czasopism należy skracać zgodnie z zasadami przyjętymi przez amerykańską Chemical Abstracts Service. Autor może, jeżeli uważa to za wskazane, podawać też tytuł cytowanych artykułów z czasopism, który będzie składany kursywą oraz numer zeszytu danego woluminu (w nawiasie, po numerze woluminu).

Redakcja potwierdza emailem otrzymanie artykułu do druku. W przypadku braku potwierdzenia prosimy o interwencję: emailem, faksem, listem lub telefonicznie.

REDAKTOR TECHNICZNY
Halina Szczegot

SKŁAD I ŁAMANIE
Jolanta Brodziak

PROJEKT OKŁADKI
Marian Wojewoda

Druk: „Drukarnia Smolarski", Józef Smolarski, 45–326 Opole, ul. Sandomierska 1. Objętość: ark. wyd. 14,75, ark. druk. 12,25. Nakład: 350 egz. + 5 nadb. aut.